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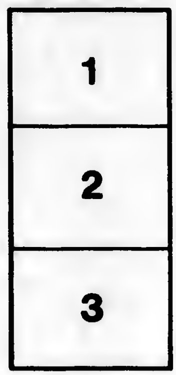

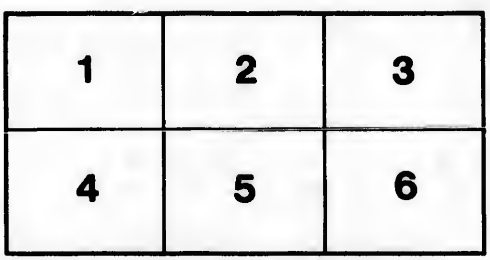

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Book Sep^t^ 3^rd^ 1864

CATECHISM

OF

AGRICULTURAL CHEMISTRY

AND

GEOLOGY.

BY

JAMES F. W. JOHNSTON, M.A., F.R.SS. L. & E.

HONORARY MEMBER OF THE ROYAL AGRICULTURAL SOCIETY OF ENGLAND, AUTHOR OF "LECTURES ON AGRICULTURAL CHEMISTRY AND GEOLOGY," &c. &c.

[*Approved by the Provincial Board of Education for use in the Schools of New Brunswick.*]

FORTIETH EDITION.

BARNES AND COMPANY,
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TO THE

SCHOOLMASTERS AND TEACHERS

OF

GREAT BRITAIN AND IRELAND.

GENTLEMEN,

HAVING written the present little work with a view to the more speedy improvement of the agriculture of our common country, I take the liberty of dedicating it to you. No class of men possesses in so high a degree the power of promoting an object so important to all. I am anxious, therefore, to secure, not only your willing support, but, if possible, your cordial co-operation also.

The land from which our crops are raised must be rendered more productive, if food is to be grown *at home* for our increasing population. But the produce can be largely increased only by the application of increased knowledge to the culture of the soil;—and it is the rising generation now under your care which must possess and apply this knowledge. Chemistry, as has been well said, is now "the key of agriculture." You can scarcely render a higher service to your country, therefore, than by imparting, along with your other instructions, the rudiments of that kind of knowledge on which its rural prosperity must so greatly depend. Few of your pupils will then escape from your hands so early as not to have already learned what may enable them, on some spot or other in after life, "*to make two blades of grass grow where only one grew before.*"

I have the honour to be,

GENTLEMEN,

Your obedient Servant,

JAMES F. W. JOHNSTON.

ADVERTISEMENT

TO THE

THIRTY-SEVENTH EDITION.

The extent to which this little Catechism has been circulated in thirty-six successive Editions at home, its translation into nearly every European language, and its introduction into the schools of Germany, Holland, Flanders, Italy, Sweden, Poland, and some of the Provinces and States of South as well as North America, while it has been gratifying to the Author, has caused him to take additional pains in improving and adding to the amount of useful information in the present Edition. By numerous alterations and additions of a practically useful kind, it has been again brought up to the present state of our rapidly advancing scientific knowledge.

The Author believes that the country teacher who may introduce this Catechism into his school will find no difficulty in making his elder classes understand the different subjects which are successively averted to. It will not be necessary to make them commit the very words of each answer to memory; they should be taught rather to make themselves masters of the matter of each, so as to be able to express the sense of the answers in words of their own.

On going over the questions for the first time, the pupil's attention may be confined to those which the teacher considers most important, or most applicable to the practice of the neighbourhood in which he lives. The other questions may be taken up on a second perusal, and an occasional general examination upon the whole book will fix the matters treated of more firmly in the minds of his scholars.

One additional observation the Author's experience of the working of this Catechism induces him to add. The teacher must above all things bear in mind that it is *not Chemistry or Geology, but Scientific Agriculture*, he is to teach. To this *idea* all his efforts must conform, and all his teaching of mere chemistry must be subordinate. He must also endeavour to satisfy the parents of his pupils, in the rural districts, that the kind of knowledge which this Catechism embraces is not only generally useful to *them*, in common with other classes of society, but that it *can be practically applied by them to their daily occupations*, and has to them, therefore, an actual money-value.

The teacher himself will find further information in the Author's *Elements* and published *Lectures on Agricultural Chemistry and Geology*; and with one or other of these works, as a help in teaching, he ought to provide himself.

CATECHISM

OF

AGRICULTURAL CHEMISTRY AND GEOLOGY.

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1. *What is agriculture?*
Agriculture is the art of cultivating the soil.

2. *What is the object of the farmer in cultivating the soil?*
The object of the farmer in cultivating the soil, is to raise the largest crops at the smallest cost, and with the least injury to the land.

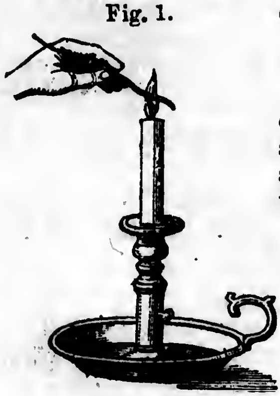
3. *What ought the farmer especially to know in order that he may attain this object?*
The farmer ought especially to know the nature and composition of the crops he raises, of the land on which they grow, and of the manures which he applies or ought to apply to the land.

4. *Has the farmer any other employment than that of raising crops?*
Yes; he rears and fattens stock, and he manufactures butter and cheese.

5. *What ought he further to know that he may conduct these operations well?*
He ought to know the composition of the animal, the kinds of food it requires, and the composition and properties of milk.

SECT. I.—GENERAL RELATIONS OF THE PLANT, THE SOIL, AND THE ANIMAL.

Fig. 1.



6. *Of how many principal parts do the plant, the soil, and the animal consist?*
All plants, soils, and animals consist of two principal parts—one which burns away in the fire, called the organic part; and one which does not burn away, called the inorganic or mineral part.

To show this fact in regard to—

a, *The Plant.*—The teacher will burn a bit of straw or wood in the candle (fig. 1), and show that while the larger part burns away, a smaller part—the ash—does not burn away.

b, *The Soil.*—He will heat a portion of soil to

Fig. 2.

redness, on a slip of sheet iron or other metal, or on the end of a knife (fig. 2). The soil will first turn black, showing the presence of organic or carbonaceous matter, and will afterwards assume a grey, brown, or reddish colour, as the blackened organic matter burns away.

c, *The Animal.*—He will take a morsel of skin, nail, flesh, bone, hair, or cheese, and burn it in either of the ways above described, and show that when all the black matter at first produced is consumed, a portion of incombustible matter or ash remains behind.

7. *What proportion of inorganic or mineral matter do the parts of plants usually contain and leave when burned?*

The parts of plants seldom leave, when burned, more than 5 lb. of ash from every 100 lb. of the dried plant.

100 lb. of dry wood seldom leave more than half a lb. of ash, dry wheat or Indian corn less than 2 lb., dry straw 5 or 6 lb., dry hay 8 or 9 lb. The leaf generally contains more mineral matter than the other parts of plants; hence the turnip, the potato, and the cabbage give from 10 to 20 lb., and tobacco from 16 to 23 lb. of ash from every 100 lb. of dry leaf.

8. *What proportion of mineral matter does dry soil usually leave when it is burned?*

Dry soil usually leaves from 90 to 98 lb. of earthy or mineral matter when burned.

Peaty soils sometimes contain 60 or 70 per cent, or even more, of combustible vegetable matter, but few of the richest alluvial soils or loams contain so much as 10 per cent. More usually 4 or 5 per cent of organic matter may be considered as an average proportion.

9. *What proportion of mineral matter do dry animal substances contain and leave when burned?*

Some, like dry flesh, skin, and hair, leave only 5 lb.; others, like dry bones, leave 50 or 60 lb. of inorganic or mineral matter from every 100 lb. that are burned.

Thus the *plant* usually contains much organic and little mineral matter—the *soil* little organic and much mineral—the *animal*, in its soft parts little, in its hard or solid parts much mineral matter.

10. *Whence do the animal, the plant, and the soil derive their mineral matter?*

The animal derives its mineral matter from the food which it eats, the plant from the soil on which it grows, and the soil from the rocks from which it has been formed.

11. *Whence do they derive their organic matter?*

The animal from its food, the plant partly from the soil and partly from the air, and the soil from the remains of dead plants and animals that have gradually been mixed with it.

SECT. II.—COMPOUND SUBSTANCES OF WHICH THE ORGANIC PART OF PLANTS AND ANIMALS CONSISTS.

12. *Of what compound bodies does the organic parts of plants chiefly consist?*

The organic substance of plants chiefly consists of woody fibre, starch, gluten, and oil or fat.

13. *What is woody or cellular fibre?*

Woody fibre is the substance which forms the greater part of all kinds of wood, straw, hay, chaff, nut-shells, &c., and of the fibres of cotton, flax, hemp, &c.

The teacher may show the fibres of hemp, of flax, of cotton, of a piece of wood, or of thin white paper, as varieties of cellular or woody fibre. They are insoluble in water, are blackened by strong sulphuric acid, and by nitric acid are converted into *gun cotton*.

14. *What is starch?*

Starch is a white powder, which forms nearly the whole substance of the potato, and about half the weight of oatmeal, Indian-corn meal, wheaten flour, and of the flour of other kinds of grain cultivated for food. (See sect. XVIII.)

For the characteristic chemical property of starch, see under *Iodine*, Q. 107, note.

15. *What is gluten?*

Gluten is a substance like bird-lime, which exists along with starch in almost all plants. It may be obtained from wheaten flour, by making it into a dough, and washing the dough with water, (fig. 3.)

Fig. 3.

The teacher will here mix flour with water into a dough, and wash the dough with water on a piece of thin muslin tied over the mouth of a tumbler or other large vessel (fig. 3), or upon a fine sieve, and will show how the milky water carries the starch through the muslin, and leaves the gluten behind; and how, after a time, the starch settles at the bottom of the water, in the form of a white powder.

16. *Is oil or fat found in all plants?*

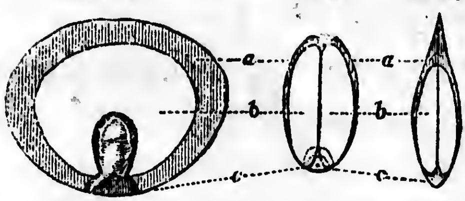
Yes, it is present in all plants, though it is generally most abundant in their seeds or nuts.

Linseed, rape-seed, hemp-seed, poppy-seed, the castor-oil bean, the walnut &c., may be mentioned or shown to the pupil in illustration of this fact.

17. *Which of these four substances is usually most abundant in plants?*

Woody fibre is the most abundant in the stems of plants, and starch in their seeds.

Indian Corn. Fig. 4. Wheat. Barley.



An examination of the structure of seeds shows the starch to be the most abundant. Thus, in the following figures of the seeds of Indian corn, wheat and barley, *a* shews the position of the oil, which exists in minute drops, enclosed in six-sided cells, consisting chiefly of gluten—*b*, the position and comparative quantity of the starch—*c*, the germ or chit, which contains much gluten.

18. *Is starch found also in the roots of plants?*

Yes, it exists abundantly in the potato and other similar roots.

The preparation of *potato-starch* or flour may be shown by grating a potato upon a common grater, and washing the grated pulp upon a sieve. The sieve will retain the fibrous matter (the cellular or woody fibre), and let the starch pass through with the water. This starch is allowed to settle, is repeatedly washed with water, and is then collected on a cloth and dried. Potato starch now forms an important article of manufacture.

19. *Of what four substances do the dry solid parts of animals chiefly consist?*

The dry solid parts of animals chiefly consist of muscle or flesh, fat, bone, and skin.

20. *What does the dry muscle or lean flesh consist of?*

It consists chiefly of blood which colours it, and of a white fibrous substance called *fibrin*.

The teacher will show this by taking a piece of fresh lean meat, and washing out the blood in successive portions of water. The *fibrin* thus obtained is nearly colourless, but is usually intermixed with a little fat.

I speak of *dry* flesh in these questions, because in its natural state 4 lb. of fresh lean meat contain 3 lb. of water, which it gives off when gently dried in an oven. This is about the same proportion of water as is contained in potatoes. (See Q. 350.)

21. *Has the fibrin of flesh any relation to the gluten of wheat?*

It is almost exactly the same thing.

22. *Does the fat of animals bear any relation to that of plants?*

A very close relation: the solid fat of olive oil, for example, is the same substance as the solid fat of the human body.

All natural fats or oils consist of a solid and a liquid part. Thus solid animal fats, like lard, tallow or butter, and vegetable fats like palm oil, yield a liquid oil when submitted to pressure, and leave a solid fat behind. So olive oil, when cooled down, becomes partly solid, and, if pressed in this cold state, yields a fluid oil, and a solid white fat. It is this solid white fat which is identical with the solid fat of the human body.

23. *What does the organic part of bone and skin consist of?*

It consists, for the most part, of gelatine or glue.

When skin or bones are boiled long in water, they give solutions, which, on cooling down, solidify into a strong jelly or glue.

24. *What is the most important difference between the organic part of the plant and that of the animal?*

The most important difference is, that the organic part of the plant contains a large per-centage of starch, while that of the animal contains none.

SECT. III.—ELEMENTARY BODIES OF WHICH THE COMPOUND SUBSTANCES CONTAINED IN THE ORGANIC PART OF PLANTS, ANIMALS, AND SOILS, CONSIST.

25. *What do you understand by a compound, and what by a simple or elementary body?*

By a compound body I understand one which can be separated into two or more other bodies; by a simple or elementary body, one which cannot be so separated.

To illustrate this, the teacher may introduce a fragment of wood, starch, flesh or fat, into a small tube, and heat it over the flame of a candle, and show how it changes into water and tarry matter, which distil forward in the tube, and a black coally matter, which remains behind. While, on the other hand, if he take a bit of sulphur, and so heat it, only sulphur will be obtained. The former are compound bodies, the latter is simple or elementary.

26. *Of what elementary bodies does the organic part of plants, animals, and soils chiefly consist?*

The organic part of plants, animals, and soils consists chiefly of four elementary bodies, known by the names of carbon, hydrogen, oxygen, and nitrogen, with minute quantities of sulphur and phosphorus.

In 1000 ℔. of dry clover, for example, the quantity of sulphur amounts to 4 or 5 ℔. only, and that of phosphorus to less than 2 ℔. In animal substances, the proportions of sulphur and phosphorus are somewhat greater.

27. *What is carbon?*

Carbon is a solid substance, usually of a black colour, which has no taste or smell, and which burns more or less rapidly in the fire. Wood-charcoal, lamp-black, coke, black-lead, and the diamond, are varieties of carbon.

The teacher will here exhibit a piece of charcoal, and show how it burns in the fire, or in the flame of a candle. He may also draw the attention of his pupils to the remarkable difference in appearance between charcoal and the diamond, though their substance is essentially the same. (Q. 78, note.)

28. *What is hydrogen?*

Hydrogen is a kind of air or gas which burns in the air, as coal-gas does, but in which a candle will not burn, nor an animal live. When mixed with common air, it will explode, if brought near the flame of a candle. It is also the lightest of all known substances, being 14½ times lighter than air.

Here the teacher will take a beer or champagne glass (fig. 5), will put into it some pieces of zinc or iron filings, and pour over them a small quantity of oil of vitriol (sulphuric acid) diluted with twice its bulk of water, and will then cover the glass for a few minutes. On putting in a lighted taper very quickly, an explosion will take place, because the hydrogen produced in the glass is mixed with common air. He will then repeat the same experiment in a phial, in the cork of which he has introduced a common gas jet, or a bit of a clay tobacco-pipe (fig. 6). After a short time, when the hydrogen gas produced has driven out *all* the common air from the

Fig. 5.

Fig. 6.

bottle, a light may be applied to the jet, when the gas will take fire quietly, and burn with a pale yellow flame. The cork and jet may now be taken out of the bottle, and a lighted taper introduced into it, (as in fig. 6), when the taper will be extinguished, while the gas itself will take fire and burn at the mouth of the bottle, where it is in contact with the air. Lastly, if the teacher possesses a small balloon, he may fill it with the gas by attaching it to the mouth of the bottle; and may thus show that the gas is so light that it will carry heavy bodies up with it through the air.

29. *What is oxygen?*

Oxygen is also a kind of air or gas. A candle burns in it with great brilliancy; animals also live in it. It is sixteen times heavier than hydrogen gas, and one-ninth part heavier than common air.

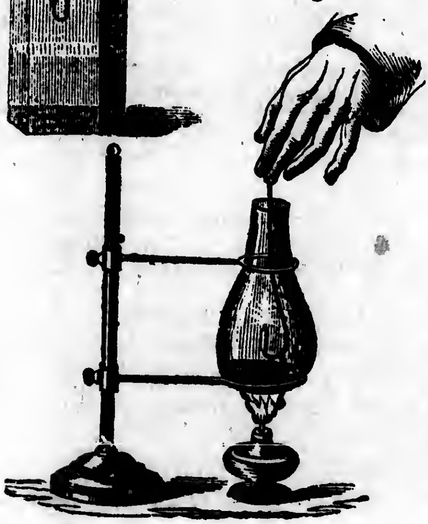
Fig. 7.

The teacher will here exhibit a bottle of oxygen gas (fig. 7), and show how rapidly and brilliantly a lighted taper, or any other lighted body burns when introduced into it.

The least troublesome mode of preparing oxygen gas is to rub together in a mortar equal weights of oxide of manganese and of chlorate of potash, (a white salt to be obtained at the apothecaries'), to put the mixture into a common Florence flask, and to apply the lamp as in fig. 8.

The oxide of manganese employed in the experiment may be washed out of the flask after it has cooled, and may be employed again, with new chlorate of potash, for any number of times.

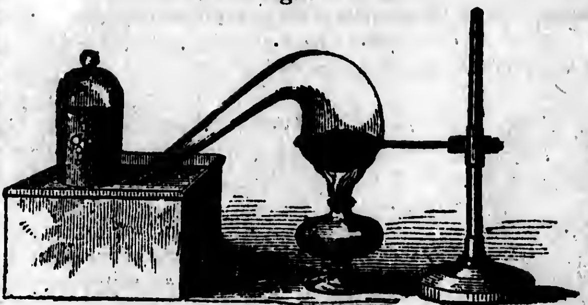
Fig. 8.



When prepared in this way, the properties of the gas may be shown in the flask itself, by introducing a lighted taper, or a bit of red-hot charcoal fastened to the end of a wire. Or, if the teacher wish to collect a bottle of the gas, he may do so by introducing the mixture into a retort, and collecting it over water, as is shown in fig. 9; or by fitting a tube and cork lightly into the flask, as in fig. 14.

The properties of oxygen may also be shown without the necessity of collecting the gas, or of preparing it in large quantity. Thus the mixture of chlorate

Fig. 9.



of potash and oxide of manganese, above described, may be put into an open tube (fig. 10), and the flame of a lamp applied for a few minutes, when a bit of red hot charcoal, or a match of which a spark is still red, will burn brilliantly, if introduced at *a*.

Fig. 10.

A very elegant method of preparing the gas is to put a few grains of pure *red oxide of mercury* into the bottom of a test tube, and to apply the heat of the lamp. Oxygen will be given off (as can be shown by putting into the tube a half-kindled match, and showing how rapidly it burns up), while metallic mercury will distil off in brilliant minute globules. This experiment the teacher may use to illustrate the meaning of the word *oxide*. (See Q. 99).

30. *What is nitrogen?*

Nitrogen is also a kind of air differing from both the other two. *Like* hydrogen, a taper will not burn, nor will an animal live in it; but, *unlike* hydrogen, it does not take fire when brought near the flame of a candle. It is a little lighter than atmospheric air.

The teacher will here exhibit a bottle of this gas, and show that a lighted taper is extinguished when introduced into it. (Fig 7).

To prepare nitrogen gas, dissolve an ounce of green copperas (called also green vitriol, or sulphate of iron) in four or five ounces of water, and pour the solution into a pint or quart bottle, as in fig. 7. Into the bottle pour also two or three table-spoonfuls of the common hartshorn (liquid ammonia) of the shops. Close it with a tight cork, and shake it well, from time to time, for half an hour. On gently loosening the cork at each shaking, air will rush in; and the process is complete when such entrance of the air becomes insensible. The air in the bottle is then nearly pure nitrogen gas, and will extinguish a taper introduced into it. Or the gas may be more quickly produced by putting into a little cup over water a bit of phosphorus, kindling it, and covering it with a bottle dipping into the water, as in fig. 11. When the burning ceases, and the bottle has become cool, the water will be found to have risen into it to some height, and the air which remains to possess the properties of nitrogen gas.

Fig. 11.

31. *Do oxygen and nitrogen gases exist in the air we breathe?*

Yes. Five gallons of atmospheric air contain one gallon of oxygen and nearly four gallons of nitrogen.

It is upon this fact that the process above given, for preparing nitrogen from the solution of green vitriol, depends. The *black* oxide of iron thrown down by the ammonia absorbs the oxygen of the air contained in the bottle, and becomes changed into the *red* oxide, leaving the nitrogen behind. (See Q. 99, note.)

32. *What is sulphur?*

Sulphur is a yellow brittle substance, which burns with a pal blue flame, and with a strong, pungent, and peculiar odour.

The teacher will show this flame by burning a commou sulphur match and he will exercise the discriminating powers of his pupils by showing them that the smell of sulphur itself, perceived by rubbing it, is very different from that of burning sulphur, or that of the water of sulphur springs (Harrowgate, &c.), and yet that all three are called by the common name of *sulphury* or sulphureous smells.

33. *What is phosphorus?*

Phosphorus is a yellowish waxy substance, which smokes in the air, shines in the dark, has a peculiar smell, takes fire by mere rubbing, and burns with a large bright flame, and much white smoke. (Q. 104, note.)

If the teacher can show these properties of phosphorus to a boy only once he will never forget them, and especially if he can also burn a fragment of phosphorus in oxygen gas.

It is an interesting fact, that upwards of 200,000 ℔. of phosphorus are used in London every year for the manufacture of lucifer matches. These are tipped with a minute portion of phosphorus, the smell of which may be perceived by bringing the match near to the nose. When the match is rubbed, this phosphorus takes fire and kindles the sulphur.

34. *Do all vegetable and animal substances contain the four elementary bodies—carbon, hydrogen, oxygen, and nitrogen—with traces of sulphur and phosphorus?*

No. The greater number contain only the three substances, carbon, hydrogen, and oxygen.

35. *Name some of the more common vegetable and animal substances which contain only these three?*

Starch, gum, sugar, oils, fats, and the fibre of wood, contain only these three elements.

36. *What vegetable and animal substances contain all the elementary bodies we have spoken of?*

The gluten of wheat, the fibrin of flesh, the curd of milk, the white of the egg, and the gelatine of bones, contain all the six (Q. 90.)

SECT. IV.—OF THE ORGANIC FOOD OF PLANTS.

37. *Do plants require food as animals do?*

Yes. All plants require constant supplies of food, in order that they may live and grow.

38. *Where do plants obtain their food?*

They obtain it partly from the air and partly from the soil.

39. *How do they take in their food?*

They take it in by their leaves from the air, and by their roots from the soil.

40. *Do plants require two distinct kinds of food?*

Yes. They require organic food to support their organic part, and inorganic food to support their inorganic or mineral part.

41. *Whence do they obtain their organic food?*

They obtain their organic food partly from the air, and partly from the soil.

42. *In what form do plants take their organic food from the air?*

In the form chiefly of carbonic acid gas.

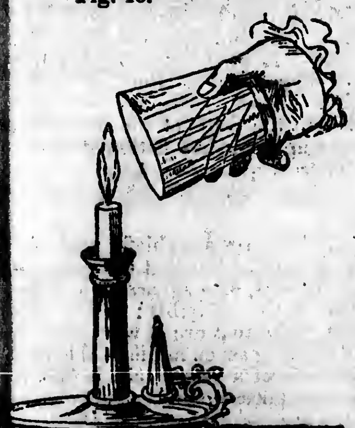
Fig. 12.

43. *What is carbonic acid gas?*

It is a kind of air which is without colour, but has a peculiar smell, and a slightly sour taste. Burning bodies are extinguished by it, and animals die in it. It is one-half heavier than common air, renders lime-water milky, and is taken up by its own bulk of cold water.

This gas is the cause of the boiling up of soda water, and of the frothing of beer, and forms nearly half the weight of all limestone rocks. The teacher will prepare carbonic acid gas by pouring either dilute muriatic acid (spirit of salt) upon bits of limestone, or vinegar upon the common soda of the shops, in a tall covered beer-glass (fig. 5), or in a bottle (fig. 7). He will show—

Fig. 13.



1°, That a burning taper is extinguished by this gas; but that it does not, like hydrogen, take fire itself, (fig. 5.)

2°, That it is so heavy that it may be poured from one glass to another, (fig. 12.)

3°, That when poured from a large tumbler glass, a common candle may be put out by it, (fig. 13.)

4°, That when passed through a decoction of red cabbage or litmus, as represented in fig. 14, it reddens the solution, and is therefore *acid* or *sour*. (See Q. 63, note.)

Fig. 14.

5°, And that, when passed through clear lime-water (fig. 14), it makes it milky, forming *carbonate of lime.*

Lime-water is made by putting a little quicklime into a bottle, filling up with water, corking, shaking, and then allowing the whole to settle. (Q. 96, note.)

44. *Does carbonic acid gas form a large part of the atmospheric air?*

No. In 5000 gallons of air there are only two gallons of carbonic acid gas.

In the higher regions of the atmosphere the proportion is greater than this. At the height of 10,000 feet it is nearly twice as much.

The teacher may here task the recollection of the boy by asking what the rest of the air consists of—in what proportions, and so on. (Q. 31). See also Q. 325, note.

45. *Do plants drink in much carbonic acid from the air?*

Yes. They drink in a very large quantity.

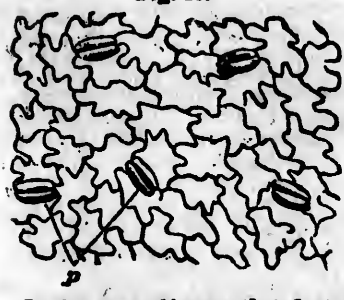
46. *How can plants drink in so large a quantity of this gas from the air, if the air contain so little?*

They spread out their broad thin leaves in great numbers through the air, which is always in motion, and thus are able to suck in the carbonic acid from a large quantity of air at the same time.

47. *How do they suck it in?*

By means of a great number of small openings or mouths, which are spread especially over the *under* surface of the leaf.

Fig. 15.



These mouths or pores are of different forms and sizes, and placed at different distances in the leaves of different plants. The annexed woodcut (fig. 15) shows in what way the oval pores *p* are distributed on the leaf of the garden balsam. The waving lines represent the walls of the leaf cells, as they appear when flattened under the microscope.

In the case of leaves *that float upon water*, the pores are chiefly upon the *upper* side of the leaf. It is a striking fact to tell a boy that there are no less than 120,000 of these pores, or little mouths, on a square inch of the leaf of the common lilac, or 60,000 on that of the white lily; and he will be able to form an idea of the number of these that are at work upon a great tree, if he is told that upon a single oak tree seven millions of leaves have been counted. One of the good effects of a heavy rain is that it washes the leaves of plants, and keeps these pores open.

48. *Do the leaves suck in this carbonic acid at all times?*

No: only during the daylight. During the night they give off a quantity of carbonic acid.

49. *What does carbonic acid consist of?*

Carbonic acid consists of carbon (or charcoal) and oxygen.

Six lb. of carbon and 16 lb. of oxygen form 22 lb. of carbonic acid.

50. *How do you prove this?*

By burning charcoal in oxygen gas, when carbonic acid gas will be formed.

The teacher will make this experiment by introducing at the end of a wire a piece of red-hot charcoal, or coal-cinder, into a bottle of oxygen gas (or into a flask full of oxygen prepared as in fig. 8), and keeping it there till the charcoal ceases to burn. He will then show that carbonic acid has been formed, because a lighted taper introduced into the bottle will be extinguished, moist litmus paper reddened, or lime-water troubled by the air it now contains.

51. *Does the plant retain both the carbon and the oxygen contained in the carbonic acid that is absorbed by its leaves during the day?*

No. It retains only the carbon, giving off the oxygen again into the air.

52. *How do you show that the leaves give off this oxygen gas?*

Fig. 16.

By putting a few green leaves under a large glassful of fresh spring-water, and setting them out in the sunshine, when small bubbles of oxygen gas will be seen to rise from the leaves, and to collect in the upper part of the glass (fig. 16).

It may be useful to the teacher to know that a very few drops of sulphuric or muriatic acid mixed with the water will promote the production of these bubbles of oxygen gas. The oxygen is supposed to be derived from carbonic acid contained in the water—of which the leaf takes up the carbon and sets free the oxygen. Hence, if pure boiled water be used, no oxygen will be separated by the leaves. But when bubbles have ceased to appear in spring water, in consequence of the carbonic acid being all decomposed, if two or three drops of sulphuric acid be added, bubbles will again be given off, showing that they are not due altogether, or in all cases, to the presence of free carbonic acid in the water.

53. *Do the leaves of plants drink in anything else from the atmosphere?*

Yes; they drink in watery vapour.

It is not necessary to the understanding of any of the practical operations of husbandry, but the teacher, if he thinks proper, may explain further, that while the leaves of plants drink in carbonic acid, and give off oxygen in the daylight, they, on the contrary, drink in oxygen and give off carbonic acid in the dark. They also give off as well as drink in watery vapour—giving off when the air is dry, drinking in when it is moist.

54. *What purpose does this watery vapour serve?*

It serves in part to moisten the leaves and stems, and to fill their cells, and partly to produce the substance of the plant itself.

How it aids in producing the substance of the plant, the teacher will illustrate by referring to the quantity of water contained in starch, sugar, &c., as explained in Q. 78, note.

55. *In what form do plants take in carbon from the soil?*

In the forms of carbonic acid, humic acid, and some other substances which exist in the black vegetable matter of the soil.

If the teacher wishes to form *humic acid*, he has only to dissolve a little common soda in water, to boil the solution upon finely powdered peat, or rich dark soil, to pour off the solution when it has stood to settle, and to add vinegar or weak spirit-of-salt to the clear brown liquid. Brown flocks will fall, which are humic acid. (Q. 78 and 85).

56. *In what form do plants derive nitrogen from the soil?*

A considerable portion of the nitrogen of plants enters them in the forms of ammonia and nitric acid.

The properties of these two substances are described in the succeeding section.

SECT. V.—COMPOSITION AND PROPERTIES OF WATER, AMMONIA, AND NITRIC ACID.

57. *What elementary bodies does water consist of?*

Water consists of oxygen and hydrogen.

58. *In what proportions do these two substances unite to form water?*

Eight lb. of oxygen united to 1 lb. of hydrogen produce 9 lb. of water.

Fig. 17.

The teacher may show *synthetically* that water is composed of these two gases, by holding a tumbler or any other cool dry glass vessel over a jet of burning hydrogen gas (fig. 17) prepared as in Q. 28, note. The glass will immediately become bedewed with minute globules of water, which will gradually collect in visible drops, and trickle down the glass. This water is formed by the union of the burning hydrogen with the oxygen of the air in which it burns.

He may also draw the attention of his pupils to the very remarkable circumstance, that liquid water, which put out all fire, should consist of two gases, one of which (the hydrogen) burns readily, while in the other (the oxygen) bodies burn with great rapidity and brilliancy.

59. *What properties of water are most important to vegetation?*

First, its property of dissolving solid and other substances; second, its property of rising in vapour, and again falling in rain or dew; and third, its property of yielding oxygen and hydrogen to the growing plant.

The teacher will show how salt or sugar dissolves in water and disappears—how water rises in vapour when it is heated or made to boil in the open air—and how the vapour in the air condenses in drops of dew on the outside of a tumbler or bottle containing very cold water, or into which a piece of ice has been introduced to cool it down below the temperature of the atmosphere.

60. *In what way is the dissolving power of water important to vegetation?*

Because it enables it to take up from the soil and convey into the roots and stems of plants the various kinds of food which plants derive from the soil. (Q. 164).

61. *How does its property of rising in vapour benefit vegetation?*

It enables the winds to carry it everywhere over the surface of the land, so as to refresh vegetation by rains and dews.

62. *How does its property of yielding oxygen and hydrogen assist vegetation?*

It enables the growing plant more easily and quickly to form the various compound substances of which its parts consist.

63. *What is ammonia?*

Ammonia is a kind of gas which has a strong, pungent, peculiar smell, is lighter than common air, and possesses *alkaline* properties.

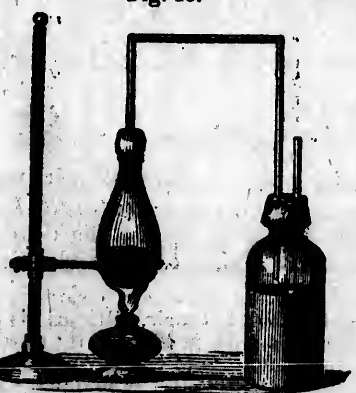
The teacher will here explain that substances called *acid* are sour to the taste, and redden vegetable-blue colors—such as a decoction of violets, of red cabbage, or of a blue substance sold in the shops under the name of *litmus*. *Alkalies*, on the other hand, have what is called an *alkaline* taste, and restore the blue colour after it has been reddened by an acid. To enable his pupils to distinguish an alkaline taste, he may allow them to put into their mouths a little hartshorn, pearl-ash, carbonate of soda, or quick-lime—all of which have an alkaline taste.

He may also prepare the gas ammonia by mixing together in a tumbler or wine-glass a little powdered quicklime with powdered sal-ammoniac, when the gas will be immediately liberated, in consequence of its lightness will rise quickly into the air, and, though invisible, may be perceived by its smell. (Q. 69, note.)

64. *Does water dissolve or absorb much ammonia?*

Yes, water absorbs between six and seven hundred times its bulk of ammoniacal gas. The common hartshorn of the shops is only water impregnated with this gas.

Fig. 18.



The teacher may show that this solution of ammonia in water restores the blue colour to vegetable blues (such as that of violets or of red cabbage) which have been reddened by an acid, and consequently that the gas with which the water is impregnated is an *alkaline* substance. He may also prepare liquid ammonia (hartshorn) by introducing his mixture of quicklime and sal-ammoniac into a small flask, fitted with a bent tube, of which the other end passes through a cork inserted into a bottle containing pure water. On applying heat to the flask, the gas passes off through the tube, and is absorbed by the water, which speedily acquires the smell, taste, and alkaline properties of common hartshorn. It is safer, in making this experiment, to keep the end of the tube just above the water in the bottle, as represented in the figure.

65. *What elementary bodies does ammonia consist of?*

Ammonia consists of nitrogen and hydrogen.

66. *In what proportions do these elements exist in ammonia?*

Fourteen lb. of nitrogen and 3 lb. of hydrogen make 17 lb. of ammonia.

One hundred lb. of ammonia contain about 17⅝ lb. of nitrogen.

67. *Under what circumstances is ammonia known to be produced naturally?*

It is produced in decaying animal and vegetable substances, in fermenting compost or manure heaps, and in fermenting urine, and it is the principal cause of the smell perceived in hot stables.

68. *If ammonia be contained in decaying or fermenting substances, how can you detect it?*

By mixing the substance with quicklime, when, if ammonia is present, its smell will become perceptible.

69. *If ammonia be escaping from such substances, how can you detect it?*

By the smell, or by dipping a rod or feather in strong vinegar or in spirit of salt, and holding it over them, when, if ammonia be escaping into the air, white fumes will become visible.

The teacher will illustrate this, by holding such a feather moistened with acid, over his hartshorn bottle, or over his mixture of sal-ammoniac and quicklime, when dense white fumes will appear, showing that ammonia is escaping from them in the form of invisible gas.

70. *What is nitric acid?*

Nitric acid is a very sour, corrosive liquid, called also *aquafortis*.

As properties that distinguish liquid nitric acid from other strong acids, it may be shown, 1°, That it stains the fingers yellow when it is too weak to corrode them. 2°, That, when poured upon a bit of copper, it becomes hot, and of a deep blue colour, and gives off red fumes. 3°, That, when poured upon sugar or starch, and heated, the same red fumes appear.

71. *What does nitric acid consist of?*

It consists of nitrogen and oxygen only.

72. *In what proportions do these two elementary bodies unite to form nitric acid?*

Fourteen lb. of nitrogen and 40 lb. of oxygen form 54 lb. of dry nitric acid.

The aquafortis of the shops consists of this dry acid mixed with much water.

73. *Under what circumstances is nitrid acid formed naturally?*

It is formed in compost-heaps and in soils during the decay of organic matter, and in the air wherever bodies are burned in it, or lightning passes through it. (Q. 28).

During the burning of wood, coal, coal-gas &c. in the air, nitric acid is produced in small quantity, by the union of minute portions of the nitrogen and oxygen of the atmosphere. In some parts of South America, the old earth of the grave-yards is so rich in nitre that it is sold to the saltpetre manufacturers, who wash it with water, and by evaporating the clear liquor in the hot air, obtain the nitre.

74. *How do ammonia and nitric acid enter into plants ?*

They are dissolved by water in the soil, and are taken up, in a very dilute state, by their roots.

Some suppose that plants absorb ammonia from the air by their leaves—a thing by no means unlikely where ammonia is present in the air. Indeed, when a little smelling-salt (carbonate of ammonia) is put into a saucer, and set in a greenhouse, the plants are said speedily to assume a greener and more healthy appearance than usual.

75. *What substances are formed in plants by the aid of nitric acid, ammonia, and other compounds containing nitrogen ?*

Those vegetable substances which, like gluten, contain nitrogen.

SECT. VI.—COMPOSITION OF WOODY FIBRE, STARCH, SUGAR, GUM, AND HUMIC ACID, AND HOW THEY ARE FORMED IN THE PLANT OR THE SOIL.

76. *Of what elementary bodies did you say that woody fibre, starch, gum, sugar, and humic acid are composed ?*

Of carbon, hydrogen, and oxygen.

77. *May we also suppose them to consist only of carbon and water ?*

Yes. Because the hydrogen and oxygen they contain are always in the proportions to form water—(of 1 to 8).

The teacher may here go back to the questions in the preceding section, as to the composition of water.

78. *How much carbon and water are contained in woody fibre, starch, and gum ?*

Thirty-six lb. of carbon and 45 lb. of water form 81 lb. of woody fibre, dry starch, or gum.

The teacher may suspend on the walls of his school-room the following table—

Carbon.		Water.			
36 lb.	and	45 lb.	form	81 lb.	of *woody* or *cellular fibre*, or of *dry starch* or *gum*.
36 lb.	and	49½ lb.	form	85½ lb.	of *loaf* or *cane sugar* or *sugar-candy*, and of *milk sugar* (Q. 395.)
36 lb.	and	64 lb.	form	100 lb.	of *fruit*, *raisin*, or *honey sugar*.
36 lb.	and	27 lb.	form	63 lb.	of *humic acid*.

He may also draw attention to the remarkable fact, that—though possessed of properties so unlike—woody fibre, starch and gum have exactly the same composition. (Q. 27, note.)

79. *What are the woody fibre, starch, gum, and sugar in the plant chiefly formed from ?*

They are principally formed from the carbonic acid and water which the leaves and roots take in from the air and from the soil.

80. *How are they formed from these two compound bodies ?*

Under the influence of light, the carbonic acid gives off its oxygen from the leaf, while its carbon unites with the water of the sap to form starch, sugar, &c.

The teacher may here revert to the functions of the leaf, and the composition of carbonic acid, (Sect. IV.)

81. *Do plants derive more of their carbon from the soil or from the air?*

They draw the greatest part of their carbon directly from the air, in the form of carbonic acid.

82. *As the air contains only a small proportion of carbonic acid, and plants suck in so much of it, may they not at length rob it of the whole of the carbonic acid it contains?*

No. Because new supplies of this gas are continually returning into the air.

83. *Whence do these supplies come?*

They come principally from three sources: from the breathing of animals, from the burning of wood and coal, and from the natural decay of animals and vegetables.

First, All animals throw off a small quantity of carbonic acid from their lungs every time they breathe. This may be shown by blowing the air from the lungs for some time through clear lime-water, by means of a small glass tube or a bit of straw, as in fig. 19, when the lime-water will gradually become milky, as it does when pure carbonic acid is passed through it (fig. 14.)

Fig. 19.

Second, The carbon which wood, coal, candles, &c. contain, when it burns in the air, forms carbonic acid gas, just as pure carbon does when it is burned in oxygen gas. (Q. 50, note.)

Third, The decay of vegetables in the air, of roots in the soil, and of the remains of animals, is only a slow kind of burning, by which their carbon is *at last* converted into carbonic acid.

Fourth, Much carbonic acid is also given off from cracks or fissures in the earth, especially in volcanic countries. This is a large and constant source of the gas, but the amount yielded by it cannot be estimated.

84. *Do animals and plants thus appear to live for each other's support?*

Yes. The animal produces carbonic acid, upon which *plants* live; and from this carbonic acid and water together, plants produce starch, &c., upon which *animals* live.

85. *How are humic acid and other similar dark-coloured substances formed in the soil?*

By the loss of a portion of their water, the woody fibre and starch of plants are converted into humic acid and similar dark-coloured substances in the soil.

The teacher, by pointing to the table (Q. 78), will show that humic acid really does contain less water than the substances from which it is formed. He ought, however, to make his pupils aware that, through the influence of the oxygen of the air, vegetable substances gradually undergo other

changes also, till their carbon is at last all converted into carbonic acid, as is stated in the note to Q. 83.

86. *What purpose is served by the humic acid and other organic compounds in the soil?*

They partly feed the plant, and partly prepare and carry in other kinds of food into its roots.

SECT. VII.—COMPOSITION OF FAT, GLUTEN, AND FIBRIN, AND HOW THEY ARE FORMED IN THE PLANT AND THE ANIMAL.

87. *What does the oil or fat of plants and animals consist of?*

It consists of carbon, hydrogen, and oxygen.

88. *Can oils and fats be represented as consisting of carbon and water, as starch and sugar can?*

No: because they contain too little oxygen.

To form water, as we have seen, there must be eight of oxygen to one of hydrogen by weight; but fats contain very much less oxygen than this, in proportion to their hydrogen.

89. *Where is the fat of the animal derived from?*

Chiefly from the fat of its vegetable and other food.

90. *What do gluten and fibrin consist of?*

They consist of carbon, hydrogen, oxygen, and nitrogen, with a little phosphorus and sulphur. (Q. 36).

The presence of sulphur in gluten, wheaten flour, oatmeal, pease-meal, hair, wool, flesh, &c., may be shown by heating a bright teaspoon or silver coin over a lamp, and dropping on it a little of the substance. The sulphur blackens the silver where the substance touches it. Less heat is required if the morsel of substance be put on the silver, be moistened with a drop of a solution of caustic potash, and be then held over the candle or lamp for a minute or two.

91. *Does the plant draw from the air by its leaves all the materials out of which it forms its gluten?*

No. The nitrogen, sulphur, and phosphorus are taken up by its roots from the soil.

Hence the importance of adding these substances to the soil, when they are either present in too small a quantity, or in a condition in which plants cannot take them up.

92. *Does the animal form the fibrin of its muscles from the elementary bodies—carbon, hydrogen, &c.—of which fibrin consists?*

No. The animal obtains it, ready formed, from the gluten of the plant.

The teacher will remind his pupils of Q. 21, in which it was stated that gluten and fibrin are nearly identical. He will then draw their attention to the interesting fact, that the plant *prepares*, in fat and gluten, what the animal afterwards *uses* or appropriates to form the parts of its body. *The plant is really the servant of the animal.*

SECT. VIII.—SUBSTANCES OF WHICH THE INORGANIC, MINERAL, OR INCOMBUSTIBLE PART OF SOILS, PLANTS, AND ANIMALS CONSISTS.

93. *Of what substances does the inorganic or mineral part of soils, plants, and animals consist?*

The mineral part of soils, plants, and animals consists of potash, soda, lime, magnesia, oxide of iron, oxide of manganese, silica, alumina, sulphuric acid, phosphoric acid, boracic acid, chlorine, iodine, bromine, and fluorine.

94. *What is potash?*

The common potash of the shops is a white powder, which has a peculiar taste, called an *alkaline* taste, and which becomes moist, and at last runs to a liquid when exposed for a length of time to the air. It is obtained by washing the ashes of burned wood with water, and afterwards boiling the liquid to dryness.

The teacher will here allow his pupils to taste potash (pearl-ash or wood ashes,) that they may become familiar with its *alkaline* taste, if they are not already so. (Q. 63, note.)

95. *What is soda?*

The common soda of the shops is a glassy or crystallised substance, which has also an alkaline taste, but which, unlike potash, becomes dry and powdery by being exposed to the air. It is manufactured from sea-salt.

The teacher will show a crystal of the common soda of the shops, and explain the meaning of the word *crystallised.*

This crystallised soda contains 62¾ per cent of water. When exposed to hot air, a part of the water escapes, and the crystals crumble to powder. By heating in a hot oven, the whole of the water is driven off, and 37¼ lb. of dry soda remain from every 100 lb. of crystals.

The common potash and soda of the shops are called by chemists *carbonate* of potash and *carbonate* of soda respectively.

They are converted into *caustic* potash and *caustic* soda by dissolving them in ten times their weight of water, and boiling with half their weight of quicklime.

Dry carbonate of soda, sold under the name of *soda-ash*, is represented as an infallible destroyer of the wire-worm.

96. *What is lime?*

Lime, or *quick*-lime is a white earthy substance, which is obtained by burning common limestone in the lime-kiln. It has a slightly burning taste, becomes hot and *slakes* when water is poured upon it, and is slightly soluble in water.

The teacher will exhibit a piece of quicklime, will allow his pupils to taste it, and will pour water upon it that it may fall to powder. They will thus become familiar with the word *slake.* (Q. 322.)

600 lb. of water dissolve about 1 lb. of quicklime, forming what is called *lime-water.* (Q. 43, note.)

97. *What is magnesia?*

Magnesia is the white, nearly tasteless powder sold in the shops under the name of *calcined* magnesia. It is extracted from sea-water, and from those varieties of limestone rock called *magnesian* limestones.

98. *What is iron?*

Iron is a hard, bluish-grey *metal*, which is manufactured in large quantities in our iron-works, and is used for a great variety of useful purposes.

The teacher will here explain the word *metal* by showing that such common metal as iron, copper, lead silver, and gold have a lustre and weight not possessed by wood, stone, and other substances to which the name of metals is not applied, and that they can be beat out under the hammer, or are *malleable*.

99. *What is oxide of iron?*

When polished iron is exposed to the air, it gradually becomes covered with rust. This rust consists of the metal iron and of the gas oxygen which the iron has attracted from the moist air, and hence it is called an *oxide* of iron.

The teacher will explain more fully that, when metals combine with oxygen, they form *new* and *compound* substances, to which the name of *oxides* is given. He may illustrate this by a reference to the *red oxide* of mercury, which, by the heat of the lamp, he had formerly resolved or *decomposed* into oxygen gas and metallic mercury. (Q. 29, note.)

There are two oxides of iron, the black and the red. (Q. 31, note.) It is the red oxide which forms common rust, and gives their red or ochrey colour to soils. The scales which fall from the anvil of the smith contain more of the *black oxide*. The ores of iron consist of these oxides. When they are heated in a furnace with coal or coke they lose their oxygen, and return to the state of metallic iron. This is what the iron smelter does.

100. *What is oxide of manganese?*

Oxide of manganese is a substance consisting of oxygen, and a metal called manganese. It is very like oxide of iron, but occurs in soils and plants only in very small quantity.

101. *What is silica?*

Silica is the name given by chemists to the substance of flint, of rock crystal, of quartz, and of common sand, and sandstone. It is very abundant in soils.

102. *What is alumina?*

Alumina is a white earthy tasteless powder, which exists in *alum*, and gives their stiffness to pipe clays and to stiff clay-soils.

The teacher will show the preparation of alumina by pouring a solution of common soda or of pearl-ash into a solution of alum. The mixture becomes milky, and the alumina falls in the form of a white powder, which may be collected on a piece of linen or cotton cloth.

103. *What is sulphuric acid or oil of vitriol?*

Sulphuric acid or oil of vitriol is a very sour, burning, heavy, oily liquid, which becomes hot when mixed with water. It is manu-

factured from burning sulphur, and exists in common gypsum, in alum, and in Glauber and Epsom salts.

One pound of sulphur produces about three pounds of the strongest sulphuric acid of commerce.

The teacher will here exhibit the oil of vitriol, and show its thick oily appearance when poured from one vessel into another—that it becomes hot when mixed with cold water—and that a bit of straw, when put into it, is charred or *burned* black.

He may here also interrogate his pupils as to the characteristic properties of the three powerful and common acids mentioned or described in this work;—the *sulphuric* being oily in appearance, becoming hot when mixed with water, charring wood or straw, and producing hydrogen gas when poured upon zinc or iron—the *muriatic* giving off white fumes into the air, forming a white cloud when a feather dipped in hartshorn is held over it, and giving off chlorine (Q. 106) when it is poured upon oxide of manganese—the *nitric* staining the fingers yellow, becoming blue and giving off red fumes when poured upon a bit of copper, and acting violently and giving off abundant red fumes when heated upon starch or sugar.

104. *What is phosphoric acid?*

Phosphoric acid is a very sour, solid substance, which is formed by burning phosphorus in the air. It exists in large quantity in the bones of animals.

100 lb. of phosphorus, when burned, form 227½ lb. of phosphoric acid.

If the teacher possess any phosphorus, he may here show again how it burns with *white fumes* in the air, and may collect these white fumes, which are phosphoric acid, by holding over them a cold glass or metal plate, or by simply burning the phosphorous in a little cup under a large glass, (fig. 20.)

Fig. 20.

A still simpler way of making his pupils acquainted with phosphorus and phosphoric acid, is to take a common lucifer-match, and to rub the end of it on a rough surface so gently as not to kindle it. If it be now brought near the nose, the smell of phosphorus will be perceived. If it be again rubbed so as to take fire, it will burn with a white flame, and will, for a short time, give a white smoke. *This white smoke is phosphoric acid.*

105. *What is boracic acid?*

Boracic acid is a white, solid substance, which exists in the common borax of the shops, and has been found in minute quantity in the ashes of some plants.

It is not yet known if this substance be really necessary to the growth of plants.

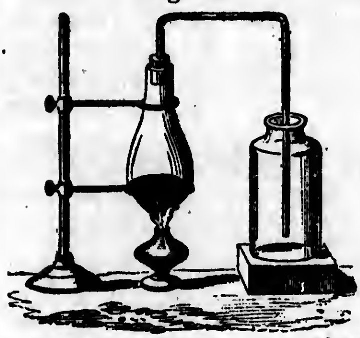
106. *What is chlorine?*

Chlorine is a kind of gas which has a greenish-yellow colour, and a strong suffocating smell, and is 2½ times heavier than common air. A taper burns in it with a dull smoky flame, and animals die in it. It exists in common salt in large quantity.

This gas is readily prepared by pouring muriatic acid on black oxide of manganese in a common flask, (see fig. 21,) and applying a gentle heat. If the flask be of colourless glass, the smell and colour of the gas, and its effects on a burning taper, may be shown in the flask itself in which the gas is prepared. In consequence of its great weight, however, it

may, by means of a bent tube fixed in the flask by a cork, be collected in an empty bottle. It will be seen to collect at the bottom and gradually to rise up as it expels the air, till the bottle is filled with the beautiful greenish-yellow gas. The teacher may then show—

Fig. 21.



a. Its weight, and how a taper burns in it, by pouring it from one vessel to another, as in fig. 12.

b. That water absorbs it, and acquires the colour and taste of the gas.

c. That it bleaches or destroys the colour of calicoes printed with vegetable colours.

d. That it kindles a bit of phosphorus introduced into the gas.

He may also advert to the remarkable fact, that this very noxious gas forms more than half the weight of the very wholesome substance, common salt—10 ℔. of common salt containing 6 ℔. of chlorine.

107. *What is iodine?*

Iodine is a solid, dark, lead-grey substance, which has a peculiar smell, stains paper and the fingers brown, gives a blue colour to wet starch, and is converted into a violet vapour when heated.

The teacher will show these several properties of iodine. Water dissolves a 7000th part of its weight of iodine, and its brownish solution gives a beautiful blue to starch. By this property iodine and starch always discover each other, a drop of the solution giving a blue colour to a crushed seed, to flour, to a slice of potato, or to water which contains starch. Iodine exists in marine plants and in fresh water plants, such as the *water-cress*, and consequently in the waters in which they grow. It has also been detected in the atmosphere, and in rain and snow water. It has been found in small quantity in the ashes of wood, and is probably necessary to the healthy growth of all our cultivated plants.

108. *What is bromine?*

Bromine is a dark, brownish-red, heavy liquid, possessed of a strong peculiar smell. It colours starch yellow, and exists in soils and plants in very minute quantity.

This substance is comparatively rare. It exists in sea-water and salt springs; but because of the small proportion in which it is present in plants, it has been separated as yet only from very few.

109. *What is fluorine?*

Fluorine is a very corrosive gas, which exists in small quantity in the bones, and especially in the teeth, of animals.

If the teacher possess a fragment of fluor spar, he may rub it to powder, moisten it with strong sulphuric acid, and heat it gently on a bit of hollow sheet-lead. Dense white fumes will be given off, which will corrode or etch a piece of glass placed upon the lead. These corrosive fumes contain fluorine.

Or a piece of bone or tooth burned black may be reduced to powder, put into the hollow lead, mixed with its own weight of oil of vitriol, and gently heated. A piece of window-glass, coated with wax on one side,

and written upon with a pointer through the wax to the glass, will, if laid close upon the leaden dish with the waxed side undermost, be etched only where the writing is. This shows the presence of fluorine in bones and teeth, but it is a more delicate experiment than the former. If the etching be very slight, it will only be visible when the glass is cleaned and breathed upon.

SECT. IX.—ORIGIN AND GENERAL CHARACTERS OF SOILS.

110. *Of what two principal parts do soils consist?*

Soils consist of an organic and an inorganic or mineral part.

111. *Whence is the organic part of the soil derived?*

It is derived from the roots and stems of decayed plants, and from the dung and remains of animals and insects of various kinds.

112. *Does this organic part form a large proportion of the soil?*

Of peaty soils it forms sometimes three-fourths, but of rich and fertile soils it does not usually form more than from a twentieth to a tenth of their whole weight when dry.

113. *Can a soil bear good crops if it does not contain a proportion of organic matter?*

Not in our temperate climates. A rich soil generally contains at least one-twentieth of its weight (5 per cent) of organic matter.

114. *Does the organic matter increase or diminish in the soil according to the way in which it is cultivated?*

Yes: it diminishes when the land is frequently ploughed and cropped, or badly manured; and it increases when the land is planted with trees, when it is laid down to permanent pasture, or when large doses of farmyard manure or of peat compost are given to it. (Q. 118.)

115. *What purpose does this organic matter serve in the soil?*

It supplies the organic food which plants draw from the soil through their roots.

116. *Do plants draw much of their organic food from the soil?*

The quantity they draw from the soil varies with the kind of plant, with the kind of soil, and with the season or climate; but it is always considerable, and is necessary to the healthy growth of the plant.

117. *If plants always draw this organic matter from the soil, will the soil not become gradually poorer and less productive?*

It will if badly managed and constantly cropped. (Q. 114.)

118. *Then, how can you keep up the supply?*

By ploughing in green crops, by growing clovers and other plants which leave long roots in the soil, by restoring all the hay and straw to the land in the form of manure, by laying down to pasture, by planting with trees, &c.

The teacher may illustrate this answer beneficially by referring to the practice of farmers in his own or the neighbouring districts, and pointing out its advantages or defects.

119. *Whence is the inorganic or mineral part of the soil derived?*

The inorganic part of the soil is derived from the crumbling down of the solid rocks.

The teacher will satisfy his pupils—by drawing their attention to the decaying walls of buildings, to the heaps of what is called *rotten-rock* (decomposed trap or whinstone), and to those of limestone, sandstone, and other kinds of gravel which are found at the foot of hills—that rocks really do crumble down in the air.

120. *Of what do all rocks principally consist?*

They all consist of more or less hardened sandstones, lime-stones, and clays, either alone or mixed together in various proportions.

The teacher may exhibit as specimens of—
Sandstone—red and white, or other freestones.
Limestone—chalk, marble, and blue or other freestones.
Clays—roofing and other slates, pipe-clay, the shale or shiver which occurs among beds of coal, &c.

121. *Do all soils consist principally of the same substances?*

Yes: all soils consist principally of sand, clay, and lime.

122. *How would you name a soil which contained one of these substances in large quantity?*

If it contained very much sand, I would call it a sandy soil; if much clay, a more or less stiff clay-soil: if much lime, a calcareous soil.

The teacher will explain the new word calcareous, derived from the Latin *calx*, meaning lime.

123. *But if the soil contained two or more of them in large proportions, how would you name it?*

A mixture of sand and clay with a little lime, I would call a loam; if much lime was present, I would call it a calcareous loam; and if it were a clay with much lime, I would call it a calcareous clay.

If a soil effervesce (give off bubbles of gas) when an acid is poured upon it, it contains carbonate of lime, and the amount of effervescence indicates the proportion of lime. (Q. 317.)

124. *What do you understand by light and heavy lands?*

Light lands are such as contain a large proportion of sand or gravel; *heavy* lands, such as contain much clay.

The teacher may illustrate this, by referring to the different kinds of lands which occur in his own neighbourhood.

125. *Which of these two kinds of land is most easily and cheaply cultivated?*

The light lands—often called barley, Indian-corn, or turnip soils.

126. *Why are these lands called barley, Indian-corn, or turnip soils?*

Because they have been found to be peculiarly fitted for the growth of barley and Indian-corn, and of turnip and other green crops.

When still lighter and more sandy, they grow rye and buckwheat better. The teacher may show his boys these different kinds of grain and root crops, if they are not already familiar with them.

127. *To what crops are stiffer soils more suited?*

Oats and clover do well upon stiffer soils, but for the strongest clay-soils, wheat, beans, and rice are most suitable.

SECT. X.—IMPROVEMENT OF THE SOIL BY DEEP PLOUGHING, SUBSOILING, AND DRAINING.

128. *Is it better to plough your land deep or shallow?*

As a general rule, it is better to plough it deep.

129. *Why so?*

One good reason is, that the roots of plants are able to descend deeper into the soil in search of food when the land is ploughed deep.

130. *Are there cases in which it is not advisable to plough deep?*

There are such cases—as when the under-soil contains some substance which is hurtful to plants, and which therefore would do harm if it were brought to the surface.

131. *In such cases as this, how would you contrive to deepen your upper soil?*

I would subsoil it—that is, plough it with the subsoil-plough.

132. *What is the effect of the subsoil-plough?*

The subsoil-plough opens the subsoil without bringing any of it to the surface,

The teacher will here explain to his pupils the difference between *common ploughing*, which merely turns over the surface soil—*subsoil-ploughing*, which stirs and loosens, but does not bring up the subsoil—and *trench-ploughing*, or trenching, which brings the subsoil to the surface. By means of occasional walks in the country, the teacher will be able to illustrate these and many other words and processes in a very interesting and instructive manner.

133. *What good follows from this subsoil-ploughing?*

The air and rains descend into the subsoil, and so change it as gradually to make it fit to be brought to the surface, and to nourish plants.

134. *Would this result be obtained more speedily and effectually if under drains were made to draw off the rain-water as it sinks through the under-soil?*

The good effects of subsoiling will in many cases scarcely appear at all, unless the land is previously drained.

135. *Do heavy or light lands usually stand most in need of draining?*

The heavy clay-lands retain water most, and should generally be drained first.

136. *Do light lands not require draining?*

Yes. Though dry at the surface, such soils are often wet beneath, and many of them have been found to pay well for draining.

The teacher may illustrate this by referring his pupils to what they may see on the sea-beach, or on the banks of a river, where the surface of the sand may be dry and drifted by the wind, while it is quite wet a few inches below.

137. *To what depth would you drain your land?*

If I could get an outfall, I would never have my drains shallower than from 30 to 40 inches.

The teacher will here explain that drains may often be made deeper, especially where there are springs or bodies of water at a greater depth, or in countries where the frost in winter penetrates so deep as to injure the drains at these depths; but that they should never be shallower than 30 to 40 inches, if the water will run away.

138. *Why would you put them so deep?*

Because the deeper the dry soil is made, the deeper the roots can go in search of food.

139. *How deep will the roots of plants go in a favourable soil?*

The roots of our grain crops, of clover and of flax, will go down three feet, and even turnip roots in an open soil will go down upwards of two feet.

140. *Can you give me any other reason?*

Yes. When my drains are so deep, I can go down 20 or 24 inches with my subsoil-plough, my spade or my fork, without any risk of injuring them.

141. *Does draining serve any other purpose besides that of carrying off the water from the land?*

Yes. It perfects the work of the subsoil-plough; it lets in the air to the subsoil, and allows the rain-water to sink down and wash out of it anything which may be hurtful to the roots of plants.

142. *Does such hurtful substances often collect in the subsoil?*

Yes, very often; and crops which look well at first often droop or fail altogether, when their roots get down to the hurtful matter.

The teacher may illustrate this answer by referring to the layers of iron-ochre, or *pan*, which in many districts are met with in the subsoil; and to such curious facts as that observed in the eastern part of Fifeshire, in Scotland, where the beans and oats, which look well up to April or May, often blacken and fail in June and July, when the roots get down to the ochrey subsoil. It is the local saying, when this happens, "that the *beans or oats have gone to Auchtermuchty*," a fair being held at that place about the time when the beans usually fail.

143. *Is there still another good reason why thorough draining improves the soil?*

Yes. If the rain sinks where it falls, it does not wash the manure out of the soil; and if it contain anything valuable to plants, this is filtered out of it before it gets down to the drains.

This power of the soil to extract soluble substances from rain-water is another reason for making drains deep.

144. *Why are many of the heaviest clays in all countries laid down to permanent pasture?*

Because the expense of ploughing and working these soils is so great that the value of the grain reaped from them when ploughed is often not sufficient to pay the farmer for his trouble.

See the Author's *Lectures*, second edition, p. 464-467, *et seq.*; or his *Elements*, sixth edition, p. 102-106.

145. *How could these heavy clay lands be rendered lighter and more cheap to work?*

By draining and subsoil-ploughing, and by the addition of lime or marl when it is required.

146. *Would the land, after this treatment, also give greater crops of grain?*

Yes. Not only would it be more cheaply worked, but it would yield a greater number of bushels of grain per acre than before, and would grow green crops in addition.

147. *Would this increase be sufficient to pay the cost of draining?*

Yes. Such is the experience of England, Scotland, and Ireland. The cost of draining clay-lands is generally paid back in three, or, at the utmost, in five years, and the crops still continue greater than before.

As to the height above the level of the sea at which draining will pay, the opinion of the most experienced practical men seems to be, that *wherever it will pay to crop land, it will pay to thorough drain it.* But my own observation carries me farther than this. I know *there is much high land which will not at present pay to crop with corn, but which would pay well in arable culture, if it were drained and subsoil-ploughed or forked.*

148. *What three points are chiefly to be attended to in making drains?*

Efficiency, cheapness, and durability.

149. *Are stone or tile drains preferred?*

Tile drains are now generally preferred, when tiles can be had at a reasonable price.

150. *What do stones drains consist of?*

Stone drains usually consist of a depth of 9 or 12 inches of stones broken to the size of road metal. (Fig. 22, *a.*)

151. *Is a tile drain efficient without a flat sole of slate or tile below it?*

As a general rule—No.

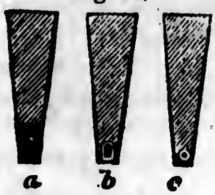
152. *Why not?*

Because it is liable to sink into the under-[illegible], and thus to become choked.

153. *What is the advantage of the pipe-tile?*

That it is cheaper, is equally efficient and durable, is lighter to carry, and contains tile and soil in one.

Fig. 22.



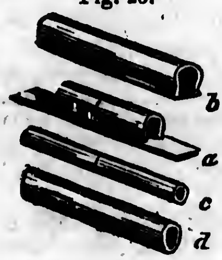
In the annexed fig. 22—

a represents the stone-drain;

b the tile-and-sole drain;

c the pipe-tile drain.

Fig. 23.



In figure 23—

a represents the common tile, as it is laid half-way along two adjoining soles;

b a pipe, having the form of the tile and sole together, made in one piece;

c the common round pipe-tile;

d the oval or egg-shaped pipe, in which, when the small end of the egg is undermost, as in the figure, a very little water causes a stream, which will scour it, and prevent sand or clay from lodging.

154. *Is a pipe with an inch bore sufficient to carry off all the rain or surface-water, as it is called, from the land?*

An inch pipe will carry off a much larger quantity of water than usually falls in rain in this country.

Only about a fifth part of the rain that falls in England, where it does not exceed 28 to 30 inches a-year, usually runs off by the drains, even in well-drained land, the rest being gradually evaporated. Many practical men, however, prefer a pipe of an inch and a half or two-inch bore, lest springs should occur in the soil, or heavy rains fall, &c.

155. *At what distance ought these drains to be put?*

Experience says, that from 15 to 18 feet is the safest distance.

Fig. 24.

Much greater distances are recommended by some. The practical man, however, should be very cautious in adopting these wider distances, even where the drains are made deeper than usual. It sometimes happens that a porous soil (*a*) rests upon an impervious clay subsoil (*b*), the surface of which is uneven, with irregular ridges and furrows, as in the woodcut. In such cases, drains cut across are found to drain to much greater distances than when cut in the direction of these ridges. It is of importance, therefore, to ascertain not only the nature of the subsoil, but the kind of surface also which it possesses, before the direction, depth, and distance of the drains are fixed upon.—(Trimmer.)

SECT. XI.—COMPOSITION AND MUTUAL RELATIONS OF THE INORGANIC PARTS OF THE SOIL AND OF THE PLANT.

126. *What purposes are served by the inorganic or mineral part of the soil?*

The inorganic or mineral part of the soil serves two purposes. *First*, it serves as a medium in which the roots can fix themselves, so as to keep the plant in an upright position; and, *second*, it supplies the plant with inorganic food.

157. *The inorganic part of the soil consists chiefly of sand, clay, and lime* (Q. 121)*; does it contain no other substances?*

Yes. It contains small quantities of eight or nine other substances.

158. *Name these substances?*

Potash, soda, magnesia, oxide of iron, oxide of manganese, sulphuric acid, phosphoric acid, chlorine, and probably iodine, bromine, fluorine, and boracic acid.

I say probably, because these four substances, though found in some plants, have not been as yet detected in the soil. It is certain, however, that fluorine must exist in it, because this substance is found in the bones and teeth of all animals.

159. *Do not these same substances exist in the ash or inorganic part of plants?* (Q. 93.)

Yes, they do; only they form a much larger proportion of the soil than they generally do of plants.

160. *Is there no special difference between the inorganic part of the soil and that of the plant?*

Yes. The soil contains alumina, while the plant usually contains none.

Here the teacher may direct the attention of his pupils to the following table:—

The *soil* contains both silica and alumina.
The *plant* silica, but no alumina.
The *animal* no alumina, and very little silica.

The feathers of birds, wool, and the hair of man and other animals, contain silica in minute quantity, but as an essential constituent. In some plants traces of alumina have been found, but it does not as yet appear to be necessary to any which we cultivate for profit. Fluorine has been detected in the ash of some plants; and being found in small quantity in the bones, blood, and milk of animals, may, as above stated, be inferred to exist also in all our usually cultivated plants and soils.

161. *You understand, then, where plants obtain all the inorganic matters they contain?*

Yes. They obtain them from the soil only.

162. *Why can they not obtain them from the air?*

Because potash, soda, magnesia, &c., do not exist in the air.

163. *You know how this earthy matter enters into the plant?*

Yes. It enters by the roots.

164. *In what state?*

In a state of *solution.* The rain and spring water dissolve and carry it into the roots.

Here the teacher may turn back for a moment to the properties of water (Q. 59), and may explain anew the meaning of the words *dissolve* and *solution*, showing how salt and sugar melt away or *dissolve* in water, forming clear *solutions* of salt or sugar, in which the substances can be recognised only by the taste, but from which they may again be obtained *unchanged* by boiling off the water.

165. *Do all soils contain every one of the inorganic substances, potash, soda, lime, &c., which you have mentioned?*

All fertile or productive soils do.

166. *Why must a fertile soil contain them all?*

Because plants require them all for their healthy growth.

167. *Do plants require them all in equal proportions?*

No. Plants must have a certain small quantity of each of them, but they require more of some substances than of others.

The teacher may illustrate this question by directing the attention of his pupils to the following table, which he should cause to be copied upon a large piece of calico, and hung upon the wall of his school-room. He can thus readily point out that, while a ton of red-clover hay leaves in all 129½ lb. of ash, when burned, there are present in this ash 55½ lb. of lime, but only 26 lb. of potash and 17½ lb. of magnesia; that red clover requires, therefore, more of one of these substances than of another, and so with the ash of the other kinds of hay mentioned in the table.

Quantity and composition of the ash left by a ton (2240 lb.) *of hay of different kinds.*

	Italian Rye-grass Hay.	Clover Hay.		Lucerne Hay.
		Red.	White.	
Potash	17	26	24¾	30
Soda	7	3½	10½	13½
Lime	13¾	55½	45½	107½
Magnesia	3	17½	14	7¾
Oxide of iron	1	1½	3½	⅞
Sulphuric acid	4	6½	12½	9
Phosphoric acid	8¾	10	20	29
Chlorine	2	4	5	6¾
Silica	81½	5	6	7⅛
	138	129½	141¾	211½

This table will suggest to the teacher many instructive questions, which his pupils will readily understand and answer when they have the table hanging before them.

168. *Are those substances, which are found in the plant in such minute quantities, really necessary to its growth?*

c

They appear to be all equally necessary, just as the few ounces of nails or glue are as necessary to the joiner in making a box as the many pounds of wood which the box contains.

169. *Suppose a soil to be entirely destitute of one of these substances, what would happen?*

Good crops would not grow upon it.

170. *Suppose it to contain a large supply of all the others, but only a small supply of some one of these substances, what would happen?*

Those plants would grow *well* upon it which require only a small quantity of that one substance; but those which require a large quantity of it would be stunted and unhealthy.

171. *Give me an example?*

If the land contained little lime, it might grow a good crop of rye-grass, and yet might not be able to grow a good crop of clover or lucerne.

By referring to the above table, the teacher may exercise the understanding of his pupils, by asking for other examples of a similar kind, which the intelligent boy will readily give by considering the numbers in the table. Thus he may say, "White clover requires more phosphoric acid than red clover and rye-grass do; therefore, if there be little phosphoric acid in the soil, white clover will not grow so well upon it as red clover and rye-grass would do," and so on.

Other tables also of a similar kind the teacher may make use of, which he will find in the Author's *Elements*, and especially in his *Lectures on Agricultural Chemistry and Geology*.

172. *Suppose a soil to be destitute of a considerable number of these different inorganic substances, what would happen?*

It would refuse to grow goods crops of any kind whatever. It would be *naturally* barren.

173. *Are any soils known to exist which are naturally barren or naturally fertile?*

Yes. Some large tracts of country, which have never been cultivated by man, are known to be naturally fertile, and others naturally barren.

174. *How is the natural difference between such soils explained, in so far as it depends on the inorganic constituents?*

In the fertile soils, all those inorganic substances exist which our cultivated crops require, and in proper proportions. In the barren soils some of these substances are or may be wholly wanting.

This answer the teacher will illustrate by a reference to the following table, which he will also hang up on the wall of his school-room. It will do much good, indeed, to have the tables contained in this Catechism suspended as *permanent fixtures* in the school-rooms of rural districts. The youngest child will soon become familiar in this way with all the names of new substances, which are so difficult for the present race of grown-up farmers to recollect.

Composition of soils of different degrees of fertility.

	Fertile, without manure.	Fertile, with manure.	Barren.
Organic matter	97	50	40
Silica (in the sand and clay)	648	833	778
Alumina (in the clay)	57	51	91
Lime	59	18	4
Magnesia	8½	8	1
Oxides of iron	61	30	81
Oxides of manganese	1	3	½
Potash	2	trace	trace
Soda, } chiefly as common salt	4	..	..
Chlorine, } chiefly as common salt	2	..	..
Sulphuric acid	2	¾	..
Phosphoric acid	4½	1¾	..
Carbonic acid (combined with the lime and magnesia)	40	4½	..
Loss	14	..	4½
	1000	1000	1000

The soil of which the composition is given in the first column, had produced crops for 60 years without manure,—*and still contained a sensible quantity of all the substances required by plants.* That of the second column produced good crops when regularly manured,—*it was in want of three or four substances only, which were given to it by the manure.* The third was hopelessly barren,—*it was in want of many substances which ordinary manuring could not supply in sufficient quantity.*

175. *May a soil be barren though it contain all the substances which plants require?*

Yes. If it contain a very large proportion of some one—such as oxide of iron or common salt—which in great quantity is injurious to the soil.

Thus the barren soil in the above table contained much more iron than either of the others, and this may have contributed to its barrenness. Land reclaimed from the sea often contains too much salt, and is infertile at first until rains and springs gradually remove the excess of salt. As little as one per cent of common salt in a soil will prevent plants from healthily germinating.

176. *How would you improve a barren soil of this kind?*

I would thorough-drain and subsoil-plough it, that the rains might sink through it and wash out the injurious matter; and I would lime it, if it required lime.

SECT. XII.—EFFECT OF CROPPING UPON THE SOIL.

177. *You said (Q. 2) that the object of the farmer is to obtain the largest crops with the least injury to the land—What do you mean by injuring the land?*

A farmer injures his land when he treats it in such a way as to cause it to produce smaller crops than it used to do.

178. *May a soil which is naturally fertile be rendered barren by continued cropping?*

If the *same kind* of cropping be carried on for a long time without a proper addition of manure, the land will gradually become less and less productive.

179. *Give me an example?*

If the same field be cropped year after year with wheat, oats, barley, Indian corn, or with hay, tobacco, cotton, the sugar-cane, or any other single crop, it will at last become unable to grow it.

180. *Why is this?*

Because all crops draw certain substances from the soil in such abundance, that, after a number of years, the soil cannot furnish these substances in sufficient quantity to the growing crop.

181. *What mineral substances do grain and root crops especially draw from the soil?*

The grain of our corn crops especially exhausts the soil of *phosphoric acid*, of *potash*, and of *magnesia;* the roots of the turnip and potato chiefly exhaust it of *potash* and *phosphoric acid.*

The teacher will illustrate this by a reference to the following table, representing the composition—in 100 lb.—of the ash of the several crops most usually grown in this country, exclusive of the tops of the turnip and potato. He must bear in mind, however, that the numbers in this and similar tables are liable to a certain amount of variation.

Composition of the ash of the grain of wheat, oats, barley, rye, Indian corn, and beans, of the straw of wheat, of the turnip root, and of the potato tuber.

	Wheat	Oats	Barley	Rye.	Indian Corn	Wheat straw	Beans	Turnip bulb	Potato tuber
Potash and soda	31	26	32	33	32½	11	45	51½	63
Lime..........	3	6	2½	5	1½	7	8⅔	11¼	2
Magnesia......	12	10	8½	10½	16	2	6½	3	5
Oxide of iron...	1	½	½	1½	¼	1	⅓	½	½
Phosphoric acid	46	44	26	48½	45	5	33	11¼	18
Sulphuric acid.	..	10½	2½	1	3	1	4½	15	4
Chlorine......	6	¼	5	?	¼	7	1¼	5½	6
Silica..........	1	2¾	23	½	1½	66	¾	2	1½
	100	100	100	100	100	100	100	100	100

The teacher will draw attention especially to the high numbers under the different kinds of grain which are seen opposite to phosphoric acid, potash, and magnesia in the above table, and will explain, *first*, that as the grain takes out more of these than of any other substances from the soil, numerous successive crops of grain must exhaust it of these more than of any other substances, while the root crops act in a similar way in regard to the potash and soda; and *second*, that this exhausting effect must

be the more perceptible, inasmuch as the substances thus removed are naturally the least abundant even in fertile soils.

Silica is abundant in all soils, and forms so large a proportion of the ash of barley, because of the thick husk with which this grain is covered. In all the grains the silica exists chiefly in the husk or bran.

He will also particularly point out the difference in the proportions of the several ingredients in the grain compared with the straw of wheat—especially the larger quantity of silica in the straw and the smaller of potash and soda—and that such a difference exists also between the straw and grain, in oats, rye, Indian corn, &c.

182. *How would you remedy such special exhaustion?*

By returning to the soil the particular substances my crops had taken out.

183. *How would you return the phosphoric acid, for instance?*

I would apply bone dust, or guano, or phosphate of lime, or some other manure in which phosphoric acid abounds.

184. *Which of the crops usually cultivated in this country may be the most exhausting?*

Of the crops usually cultivated and sold in this country, hay *may* be the most exhausting.

185. *How so?*

Because it carries off so much from the soil.

Besides organic matter, a ton of dry hay carries off from 130 to 210 lb. of mineral matter from the soil. (Q. 167, note.)

186. *Why do you say it may, and not that it necessarily does, exhaust the land most?*

Because, in good husbandry, hay is not sold off the farm, but is made into manure and returned to the land.

187. *Ought no crops, then, to be sold off the farm?*

Any crop may be sold off without permanent injury to the land, provided as much, of everything, as the crop carries off, be restored to it again in the form of good manure.

188. *But with any kind of cropping, may not a fertile soil be at length made unproductive?*

Yes; if the crops are carried off the land, and what they draw from the soil is not restored to it.

189. *How is this explained?*

Every crop takes away from the soil a certain quantity of those substances which all plants require. If you are always taking out of a purse, it will at last become empty.

190. *Then you liken exhausted soil to an empty purse?*

Yes. The farmer takes his money out of the land in the form of crops; and if he is always taking out and putting nothing in, it must at last become empty or exhausted.

191. *But if he puts something into the soil now and then, he may continue to crop without exhausting it?*

Yes. If he puts in the *proper substances, in the proper quantities, and at the proper times*, he may keep up the fertility of his land perhaps for ever.

192. *How much of everything must the farmer put into his land to keep it in its proper condition?*

He must put in at least as much as he takes out.

193. *To make his land better, how much must he put in?*

He must put in more than he takes out.

194. *But if he is to put into the land as much or more than he takes out, where is his profit to come from?*

His profit consists in this, that he takes off the land what he can sell for much money, and he puts in what he can buy for comparatively little money.

195. *How do you mean?*

I mean, that if I sell my wheat, oats, Indian corn, hay, or turnips, I get a much higher price for them than I afterwards give, when I buy them back again in the form of stable or other manures.

196. *Then the farmer can really afford to put as much upon his land as he takes off, and yet have a profit?*

He can. He puts in what is cheap, and takes off what is dear.

The teacher may avail himself of this occasion to point out how beautifully and bountifully the earth and the plant are made to work into the hands of the practical farmer, by *converting into valuable produce what he lays on in the form of a worthless refuse*; and how they always do most for the skilful, the prudent, and the industrious.

197. *What do you call the substances which the skilful farmer thus puts into his land?*

They are called *manures*; and when putting them in, the farmer is said to manure his soil.

198. *What substances are to be considered as manures?*

Anything that furnishes food to plants may be called a manure.

199. *What do you understand by farm or fold-yard manure?*

The mixed straw and droppings of animals, which collect in fold-yards or stables where cattle are kept.

200. *What do you understand by portable manures?*

Such as are of small bulk or weight compared with fold-yard manure, and can easily be transported to great distances.

201. *What is the advantage of such portable manures?*

That they can be brought from foreign countries, carried far inland, or carted up to high districts, and yet be applied with profit by the farmer.

202. *Name some of these portable manures?*
Guano, bones, rape dust, pigeons' dung, phosphate of lime, gypsum, nitrate of soda, sulphate of ammonia, and many others.

203. *How many principal kinds of manures are there?*
There are three principal kinds—vegetable manures, animal manures, and mineral manures.

SECT. XIII.—OF VEGETABLE MANURES.

204. *What do you mean by vegetable manures?*
By vegetable manures, I mean those parts of plants which are usually buried in the soil for the purpose of making it more productive.

205. *Name the most important of the vegetable manures?*
Grass, clover, straw, hay, potato or turnip tops, rape-dust, peat or bog stuff, sea-weed, &c.

206. *Is green grass ever used for manuring the soil?*
Yes. The soil is manured with green grass when grass land is ploughed up.

207. *Would you bury the sods deep, if you were ploughing up grass land?*
So deep that they would be sure to rot. Yet I would keep them so near the surface, that the roots of the young grain could feed upon the decaying grass.

208. *Are any other plants ploughed in green for the purpose of manuring the soil?*
Yes. Clover, buckwheat, lupins, white beans, white mustard, rape, rye, broom, and, in some places, even young turnips are ploughed in green to enrich the soil.

209. *Into what kind of soils would you plough in a green crop?*
Into light and sandy soils, and into such as contain little vegetable matter.

210. *Is not sea-weed or sea-ware a very valuable manure?*
Yes. Wherever sea-weed can be obtained in large quantity, it is found to enrich the soil very much.

Sixteen loads of it are reckoned equal to 20 tons of farmyard manure. The use of sea-weed has doubled the produce of the Isle of Thanet in Kent; and on the Lothian coasts it adds 20s. an acre to the rent of land which has a right of way to the sea. On the western bays of Ireland a boat-load containing four carts may be had for a shilling; and on Galway Bay alone, in the season of 1854, about £13,000 was paid by the farmers for this manure.

211. *How is it employed?*
It is spread over the land, and is either ploughed in, or is allowed to rot and sink in, or it is made into a compost. Into the potato drills it is often put in a fresh state, care being taken to prevent the

potato sets from touching the sea-weed, by putting a little earth between them.

When the potato sets are allowed to touch the sea-weed, they are often observed to rot.

212. *When used in this last way, does it give large crops of potatoes?*

Yes. On the east and west coasts of Scotland and Ireland it gives large crops of potatoes, but often of inferior quality.

The crop is often watery when raised with fresh sea-ware; but if the sea-weed be ploughed in early in the season, before the potato-planting, or if the sets are put in, and covered first with soil, this with sea-ware, and this again with soil, &c., the potatoes are as dry as when raised by farm-yard manure.

213. *How would you prefer to make a compost of sea-weed?*

I would mix the sea-weed with earth, and with shell-sand or marl, if they were to be had, and would turn over the mixture once or twice before using it.

214. *Are there any common green vegetables that are ploughed in with advantage?*

Yes. Potato or turnip tops dug in, when the roots are lifted, make the next year's grain crop better.

Potato and turnip tops ploughed in make the succeeding barley and wheat crops much better. About Edinburgh, the turnip tops thus used are considered equal to 8 tons of farmyard manure, or £2 an acre. In Northumberland, they have been found to add 6 or 8 bushels to the after-crop of wheat. Some say, however, that the clover which succeeds the grain crop is worse when the tops have been ploughed in; that it is sickly, and sometimes fails altogether. This may arise from the soil being kept too open by the green manure, and might probably be prevented by the use of the clod-crusher (a heavy, toothed, iron roller.)

Some think it better to leave the turnip tops to rot on the surface than to plough them in green; but I believe general experience is against this opinion. Something, probably, depends upon the lightness or heaviness of the soil.

215. *How can you get the largest quantity of green manure in the form of potato tops?*

By pulling off the blossoms, the tops are kept in a green state till the potatoes are dug up, and thus give much green manure.

216. *In what form is hay usually employed as a manure?*

Hay is usually given to the horses and cattle, and afterwards put upon the land in the form of their dung.

217. *In what form is the straw of our grain crops used as a manure?*

Straw, in some places, is cut and used in feeding the cattle; in other places it is partly given to the cattle, and partly trodden among the litter; while in places where few cattle are kept, it is sometimes rotted with water and a little cow-dung, and put on the land in a half-fermented state.

218. *In what state of fermentation would you prefer putting your straw into the land?*

That would depend upon the kind of land.

219. *Suppose you had to manure light land for a green crop?*

Then I would like to have my straw pretty well fermented, and mixed with the droppings of a good many cattle.

220. *But suppose you were manuring heavy clay-land during the naked fallow before a crop of wheat?*

I would then rather have my straw more loose and unfermented: it would help to keep my land open.

This general rule may not apply to all even of our *heavy* clay-lands. Even stiff clays vary in quality, and circumstances may render inexpedient in some localities what, as a *general* practice, is the best that can be recommended.

221. *What are rape, colza, cotton, and lint seed cakes and dust?*

Cake is the name given to the refuse that remains when rape, colza, cotton, or lint seed is crushed in the mill, to squeeze out the oil. When the cake is broken to powder, it is called dust.

222. *How is rape-dust applied as a manure?*

It is applied to turnips or potatoes either in place of the whole or of a part only of the common farmyard dung; and in many parts of England it is used with great profit as a top-dressing to the young wheat in spring.

Used alone for turnips, as much as 16 or 20 cwt. an acre is applied; and, as a top-dressing for wheat, from 3 to 5 cwt. per acre. In Flanders, colza, hemp-seed, and poppy-seed cakes are generally mixed with the liquid manure so much employed in that country. Cotton-seed cake is not much known as yet in this country; but it is equal in value with the rape-cake as a manure, and is likely to come into extensive use.

223. *To what soils may peat or bog stuff, or swamp mud, be applied with most advantage?*

To light soils, and to such as are poor in organic matter.

224. *How would you prepare the peat or bog stuff for being applied to the land?*

I would ferment it by mixing it with one-third of farmyard manure, or by spreading it in the fold-yard; or I would make it into a compost with earth and quicklime or marl.

Crushed peat-charcoal, now sold in Ireland at 50s. a ton, is excellent for absorbing liquid manures, and for removing the smell of nightsoil, pigs' dung, &c.

SECT. XIV.—OF THE PARTS OF ANIMALS USED AS MANURES.

225. *What parts of animals are most important as manures?*

The blood, flesh, bones, hair, and wool of animals, and the bodies and refuse of fish.

226. *In what form is blood usually employed as a manure?*

It is usually mixed up with other refuse in the dunghills of the butchers. Some of it is dried, and sold as a manure. In this dry

state it is applied as a top-dressing to corn and grass, or is drilled in with the seed, and is one of the most powerful manures we possess.

227. *How is flesh employed as a manure?*

The flesh of dead horses, cows, and dogs, buried in soil or sawdust, with a little marl, make a most enriching compost.

228. *In what form are bones usually employed as a manure?*

Bones are crushed in mills, and then sifted into the various sizes of inch bones, half-inch bones, and dust, and are thus applied to the land.

Besides the bones of home growth used as a manure, 40,000 tons of bones are yearly imported, and chiefly for this purpose.

It is only about sixty years since bones began to be much used in England. When, fifty years ago, it was proposed to use them in Wigtownshire, the objection was, "They'll do naething but breed maggots to eat everything off the land!"

229. *In which of these forms do they act most quickly?*

They act most quickly in the form of dust, but they do not act for so long a time.

230. *To what soils are they most profitably applied?*

Bones are most profitably employed on light loams, or on well-drained lands, instead of the whole or of a part of the farmyard manure. When employed without farmyard manure, they are often mixed with wood or coal ashes, and drilled in with the turnip seed.

231. *Would you raise all your turnip crops with bones alone?*

No. If I raised one crop of turnips with bones alone, I would raise the next crop on the same field with farmyard manure alone, if I could get it.

It is one of the most important results of the recent application of refined chemical analysis to the examination of soils and manures, that, upon soils which are poor in phosphates, excellent crops, both of turnips and wheat, may be raised by the use of bones; while in such as are rich in phosphates (Q. 285), bones often produce little apparent benefit; while rape-dust, woollen rags, the salt of ammonia, and the nitrates of potash and soda, are applied with great profit both to grain and root crops.

The practical importance of geology becomes apparent, when it is known that the inspection of a geological map enables us to point out where soils rich or poor in phosphates are likely to occur. (See the Author's *Elements*, 6th edit. p. 103.)

232. *Are bones ever applied to grass lands?*

Yes. To grass lands that have long been pastured for dairy purposes, as in the county of Cheshire in England;—or eaten off by growing stock, as in many hill pastures, they have been applied with great profit.

233. *What do bones consist of?*

Bones consist of *gelatine* or glue, which may be partly extracted

by boiling them in water, and of bone earth, which remains behind when bones are burned.

Here the teacher may exhibit a bit of *glue*, and make the boys acquainted with its properties and uses. He may also burn a small splinter of bone in the flame of a lamp or candle, and show that, though the organic part of the gelatine burns away, the inorganic part, or bone-earth (*phosphate of lime*), remains behind.

The weight of what thus remains is equal to about two-thirds of that of the *perfectly dry* bone, but only to one-half of the weight of bones as they are usually sold and applied to the land.

234. *Is the glue or gelatine of bones a good manure?*

Yes, it is a powerful manure. It assists very much, on some soils, in pushing forward the young turnip-plant, when this crop is raised by the use of bones.

235. *What does bone earth chiefly consist of?*

It consists chiefly of phosphoric acid and lime.

100 ℔. of *bone-earth*, as it is obtained by burning bones, contain 40 to 45 ℔. of phosphoric acid. (Q. 285.)

236. *Does this earth of bones act as a manure?*

Yes; because all plants contain, and therefere require, for their healthy growth, a certain quantity of lime and phosphoric acid. (See tables appended to Q. 174 and 181.)

237. *Why do dairy pastures especially require bones?*

Because milk and cheese contain bone-earth; and if these be carried away and sold off the farm for a number of years, the land is robbed by degrees of this bone-earth more than of any other substance. Only those grasses can then grow which require comparatively little bone-earth.

Every ten gallons of milk contain about half a pound of bone-earth. A cow, therefore, which gives twenty quarts a day, takes nearly 2 ℔. of bone-earth from the soil every week. To return these 2 ℔. to the soil, 3 ℔. of dry bones, or 4 ℔. of common bone-dust are required.

Again, every 100 ℔. of cheese contain about 2½ ℔. of bone-earth, requiring 5 ℔. of bone-dust to replace them.

238. *And what effect follows from adding the bones to old dairy pastures?*

The bones supply the bone-earth of which the land had been robbed. New or more healthy grasses then spring up, which contain much bone-earth, and these, when eaten by the cow, produce milk in greater abundance and richer in cheese.

239. *Are bones applied in any other form?*

Yes. They are sometimes made to crumble down by fermentation, and are sometimes dissolved in sulphuric acid (*oil of vitriol.*)

240. *How are bones made to crumble by fermentation?*

The crushed bones are moistened and mixed with half their bulk of sand or soil, when they heat and gradually crumble to a fine powder.

241. *How do you dissolve bones in sulphuric acid?*

About equal weights of bone-dust and of acid are taken. The acid is diluted with one or two waters, and poured upon the bones, and the mixture is stirred occasionally for two or three days.

The teacher may show how this is done, by mixing the bone-dust and acid in a common tumbler, and may explain that the liquid or *paste* obtained may either be further diluted with thirty or more times its bulk of water, and applied directly to the land with a water cart, or may be dried up with powdered charcoal, dry peat, sawdust, or soil, and drilled in as bones usually are. The relative proportions of bones and acid may also be varied, two or three of bones being sometimes used to one of acid.

242. *What is the advantage of thus reducing and dissolving the bones?*

One of the chief advantages is, that the substances of which the bones consist are very minutely divided, and made more soluble in water. They thus enter more readily into the roots of plants, so that a smaller quantity produces an equal effect upon the crop.

In light, open, gravelly, *quick* soils, the bones are, in Annandale, found more economical when applied in the dry crushed state to the turnip crop —in slowly acting and stiffer soils, when previously dissolved. Generally speaking, however, all manures are believed to go farther when brought into a liquid state. Horse dung is said to go even *five* times as far (?)

243. *Is hair much used as a manure?*

No. Hair is generally too expensive to be used as a manure in this country. In China, where the people's heads are all shaved every ten days, the shavings are collected for manure; and the sweepings of our hair-cutters' rooms might also be employed with profit.

244. *In what form is wool used as a manure?*

In the form of woollen rags. Mixed with earth, woollen rags make an excellent compost. They are much used in England for manuring hop vines, and in Holland for potatoes and turnips.

The teacher may here describe the hop plant, and explain the purpose for which it is grown and employed by the brewers.—(See the Author's *Chemistry of Common Life*, vol. ii. p. 39.)

Hair and wool are remarkable for containing about 5 per cent of sulphur.

245. *Are fish ever used as a manure?*

Yes. Along many parts of the coast, fish and fish-refuse are obtained in such quantities as to be applied economically as manure.

246. *What kind of fish-refuse is usually employed as a manure?*

Near the fish-curing stations, the guttings and cleanings of the herring and pilchard, and the heads of the cod, are extensively employed as a manure.

On some parts of our coasts, sprats and other fish are caught in such abundance as to be applied in bulk to the land. On the shores of New England, 750 tons of fish have been caught at a single haul, and sold to the farmers at 2s. 6d. a cart-load.—(See the Author's *Elements*, 6th edition, p. 209.)

247. *How are fish, and fish-refuse, best used?*

The best way is to make them into a compost with earth and a quantity of marl, if it is to be had, and to turn over the mixture once or twice before using.

Some as the least troublesome way, spread them in the fresh state upon the land; but when used in this way the loss is great, and the stench very nauseous.

248. *Could fish, or fish-refuse, not be converted into a valuable portable manure?*

Yes; by drying with artificial heat, and reducing to powder.

In cleaning the fish at Newfoundland, half the weight of the cod is thrown away. This amounts at present to 60,000 tons of offal every year. The seal fishery on the same coast yields as much more. Could all this be economically dried, it would yield an unfailing yearly supply of rich portable manure.

SECT. XV.—OF THE DROPPINGS OR DUNG OF ANIMALS.

249. *What kinds of animal dung are most commonly employed as manures?*

Nightsoil, horse-dung, cow-dung, sheep's dung, pigs' dung, and birds' dung.

250. *Which of these is the most valuable?*

In general, nightsoil and birds' dung are the most valuable; next to these is horse-dung; after that, pigs' dung; and, lastly, cows' dung.

251. *Why is nightsoil so valuable?*

Because men generally live upon a mixture of animal and vegetable food, the former of which renders the dung richer.

252. *Why is horse-dung richer or hotter than cows' dung?*

Because the horse voids little urine compared with the cow.

253. *What is the principal objection to using pigs' dung?*

The disagreeable smell and taste it is said to give to the crops raised by the use of it.

It gives a taste even to tobacco manured with it. (See Q. 273, note.)

254. *What is the best way of using pigs' dung?*

The best way is to make it into a compost, or to mix it with the dung of other animals.

255. *Why is cows' dung colder and less liable to ferment than most other kinds of dung.*

Because the large quantity of urine voided by the cow carries off a greater proportion of that which would otherwise cause it to ferment.

A stall-fed milk-cow, voids from 2000 to 3000 gallons of urine in a year, and this carries with it a large proportion of the soluble saline and other substances derived from the food.

256. *In what respect does the mixed dung of animals differ from the food on which they live?*

It differs principally in containing a less proportion of carbon,

and a greater proportion of nitrogen and of saline matter, than the food they have eaten.

257. *How does it come to contain less carbon?*

Because animals as they breathe throw off, through their lungs, a large quantity of the carbon of their food.

258. *In what form does the carbon of the food come from the lungs during breathing?*

In the form of carbonic acid gas. (Q. 88, note.)

259. *How much carbon does a man give off in this form from his lungs in a day?*

A full-grown man gives off from his lungs about half a pound of carbon in a day, and a cow or a horse eight or ten times as much.

260. *Do all the nitrogen and saline matter of the food remain in the mixed dung and urine of animals?*

Yes; nearly all the nitrogen and saline matters remain mixed with a smaller quantity of carbon than was contained in the food.

261. *Is this larger proportion of nitrogen and saline matter one cause of the greater activity of the dung of animals?*

Yes; it is one of the principal causes.

Dry matter, in the form of animal droppings, is more fertilising than an equal weight in the form of the vegetable food on which the animals have lived, for the reasons above stated among others.

262. *What form does this nitrogen assume during the fermentation of animal manures?*

It assumes, for the most part, the form of ammonia. (Q. 67.)

263. *Is this ammonia a fertilising substance?*

It generally is.

264. *How does ammonia enter into the roots of plants, when it is formed in the manure?*

It is dissolved in the soil by water, and is then sucked in by the roots.

265. *What substances are formed in plants by the aid of this ammonia?*

The gluten and other substances containing nitrogen are formed in part by the aid of this ammonia. (Q. 75.)

266. *Is this ammonia, then, a very important ingredient in our common manures?*

Yes; because nitrogen, in some shape or other, is absolutely necessary to the growth of plants.

267. *In which part of the droppings of animals, the solid or the liquid part, is ammonia produced in greatest abundance?*

It is produced in the greatest abundance in the liquid part, especially of the droppings of the cow.

268. *Is it not of great importance, therefore, to preserve this liquid part?*

Yes; it is of the greatest importance, though it is too often allowed to run to waste.

A thousand gallons of cows' urine have been found by experiment to be equal, upon grass, to two cwt. of Peruvian guano, and upon turnips superior to twenty cart-loads of good farmyard manure.—*Kinninmonth.* Copiously applied after each cutting, it will produce six heavy cuttings of Italian rye-grass in a single season.

269. *How would you collect the liquid manure of your farmyard?*

I would make a large covered tank or cistern, in or close by my farmyard, in which I would collect it.

The tank, besides being covered, should be separated into two divisions by a partition wall built in the middle of it. Each division should be capable of containing one or two months' supply of the liquid.

When the one is full, the stream should be turned into the other; and when this also is full, the liquid in the first division will be fermented, or ripe enough for laying upon the land. A little slaked lime may be thrown with advantage into each division, when the *fresh urine* begins to flow into it. (See Q. 278, note.)

270. *How would you use this liquid manure?*

I would pump it occasionally upon my dung-heaps, so as to promote their fermentation; or I would pour it upon my compost-heaps, to enrich them.

271. *Would you not employ it alone as a manure?*

Yes. During the spring and summer I would dilute it with once or twice its bulk of water, if necessary; and after it had fermented for some time, I would put it on my grass land, on my young clover, rye-grass, cabbage, or on any other young crops.

In some farms the application of liquid manure has lately been extensively and profitably made by means of pipes which convey it into the field.

272. *Is there any important difference between the fermented urine of our cattle, and the drainings of our fermenting dung-heaps?*

Yes. The fermented urine of our cows, horses, and sheep contains potash, soda, and ammonia, but no phosphates, while the drainings of the dung-heaps almost always contain phosphates.

273. *Is there any difference of this kind between human urine and that of the horse, cow, sheep, and pig?*

Yes. The urine of man and that of the pig contain phosphates; those of the horse, the cow, and the sheep contain none.

The teacher will explain to his pupils how it follows from this fact, *first*, that upon most soils human urine and that of the pig are more valuable manures; and, *second*, that all the phosphates of their food remain in the solid excrements of the horse, the cow, and the sheep.

274. *Is there any other liquid containing ammonia which might be employed as a liquid manure?*

Yes. The ammoniacal liquor of the gas-works, diluted with four or five times its bulk of water, should be collected and employed in the same way as the liquid manure of the farmyard.

Much of this liquor is now employed for the manufacture of salts of ammonia.

275. *Does birds' dung form a valuable manure?*

Yes. Pigeons' dung especially is a very rich manure; and the dung of sea-birds has lately been introduced from South America with great advantage, under the name of guano.

In Flanders, the dung of one hundred pigeons is valued at 25s. a-year.

In 1845 as much as 283,300 tons of guano were imported into Great Britain and Ireland; in 1851, 245,016 tons; and in 1852, 130,000 tons. This ought to produce at least three times its own value in grain.

276. *To what crops can guano be profitably applied?*

It may be profitably applied as a top-dressing to the young grain or grass crops; or it may be used instead of the whole or of a part of the usual application of farmyard dung, for the turnip and potato crops.

277. *In using it for the turnip or potato crops, ought it to be allowed to come in contact with the seed?*

No. It is better either to cover it, or to mix it with a quantity of earth, so as to prevent the seed from touching it.

278. *Is it proper to mix guano with quicklime?*

No. Because the quicklime sets free the ammonia contained in the guano, and causes it to escape into the air.

Here the teacher may mix a little slaked lime with a spoonful of guano in a wine-glass, and let his pupils smell the ammonia which will be given off; or he may hold over the mixture a rod or feather dipped in vinegar or muriatic acid, and show the white fumes. If he have no guano, he may use a little *sal-ammoniac*, or a little *sulphate of ammonia* instead; and may explain or show, by a similar experiment, that *quick*-lime will in the same way drive off the ammonia contained in liquid manure or nightsoil, and in horse or farmyard dung, if it be mixed with any of these, *after they have begun to ferment*.

It is of practical importance to bear in mind that quicklime does not drive off ammonia from the *fresh* droppings of birds or animals. It rather tends to preserve fresh droppings from fermentation and from the loss of ammonia. Hence fresh nightsoil is dried with less loss when previously mixed with quicklime. Hence also quicklime may be added with safety to fresh urine, though it may expel ammonia from such as has fermented.

279. *Is it better to use guano alone, or in place of one-half only of the usual application of farmyard manure?*

In raising turnips and potatoes, it is better husbandry to use it mixed with, or along with, one-half manure.

280. *Why is it better husbandry?*

Chiefly because the guano, when used alone, does not supply to average soils a sufficient quantity of organic matter to maintain them in the most productive state.

281. *How much guano would you apply per imperial acre?*

About two cwt. per acre, as a top-dressing for the grain crops,

and two or three cwt., when used instead of half-dung, for potatoes and turnips.

Guano is also used with advantage for turnips, along with dissolved bones, 1¼ cwt. of guano an acre will give the plant a start, and 8 bushels of bones will then carry it on to maturity.

282. *Would you make your farmyard manure loose and open, or would you tread it down and cover it?*

I would tread it down with stock, and both make and preserve it under cover, if I conveniently could.

283. *Why so?*

Because the manure so prepared loses less by evaporation and the action of the sun and rain, and is therefore richer and of better quality.

Lord Kinnaird found that two parts of the same field dressed with equal quantities, the one of manure prepared under cover of a roof and trodden down by cattle, the other of manure from the open fold-yard, gave in

	Covered.	Uncovered.
1851, . .	11¾ tons.	7½ tons of potatoes.
1852, . .	54 bushels.	45 bushels of wheat.
.	and 215 stones.	156 stones of straw.

SECT. XVI.—OF SALINE AND MINERAL MANURES.

284. *Name the most important mineral and saline manures?*

The most important mineral and saline manures are phosphate of lime, nitrate of soda, sulphate of soda, sulphate of magnesia, sulphate of ammonia, common salt, gypsum, kelp, wood-ashes, soot, and lime.

285. *What is phosphate of lime?*

Phosphate of lime is a whitish earthy substance, consisting of lime and phosphoric acid, which in many places is dug up as a mineral, and is used for agricultural purposes.

This phosphate is nearly the same thing as the *bone-earth* already spoken of, (Q. 235.) It occurs abundantly in some geological formations in North America, and in some beds of the *green-sand* and of the *crag* of England, and is contained, to a small and variable extent, in all limestones. The discovery of these phosphate beds is one of the most important of the benefits which science has recently bestowed upon practical agriculture.—(See the Author's little work *On the Use of Lime in Agriculture*, pp. 236 and 258.)

286. *How is the mineral phosphate used as a manure?*

It is ground to fine powder, and then dissolved, like bones, in sulphuric acid, and applied to the corn and root crops.

In this dissolved state it is sold under the name of *super-phosphate* of lime. The same name is often given also to dissolved bones, and to mixtures of the two.

287. *What is nitrate of soda?*

Nitrate of soda is a white, salt-like (saline) substance, which is

found in the earth in some parts of Peru, and is often applied with great advantage as a top-dressing to grass land and to young corn.

To show the difference between nitrate of soda and common salt, with which it is often adulterated, sprinkle a little of each on a red-hot cinder. The common salt will crackle and leap in the fire (*decrepitate*), while the nitrate of soda will cause a bright flame or burning (*deflagration.*) Saltpetre (*nitrate of potash*) will deflagrate like nitrate of soda; but if there be much common salt present in either of these nitrates, it will first *decrepitate* and then *deflagrate.*

288. *What does nitrate of soda consist of?*

It consists of nitric acid and soda.

54 ℔. of nitric acid and 31 ℔. of soda form 85 ℔. of nitrate of soda.

The teacher may take an opportunity about this place of verbally explaining the kind of terms by which chemists denote combinations of the nitric, sulphuric, phosphoric, and carbonic acids, with potash, soda, lime, and magnesia; that when carbonic acid combines with any of these substances, it forms a carbon*ate*, phosphoric acid a phosph*ate*, sulphuric acid a sulph*ate*, nitric acid a nitr*ate*. Hence, that *phosphate of lime* denotes a combination of phosphoric acid with lime; *sulphate of soda*, a combination of sulphuric acid with soda; and so on.

289. *Upon what does the beneficial action of nitrate of soda on plants depend?*

Chiefly upon its supplying nitrogen and soda to the growing crops.

100 ℔. of nitrate of soda contain 16½ ℔. of nitrogen.

290. *What quantity would you lay upon an acre?*

From 1 cwt. to 1½ cwt. as a top-dressing in spring.

In Norfolk, such a top-dressing is found to increase the wheat crop by 7 or 8 bushels an acre. Similar results have been obtained in the Lothians. The effects are often better when it is applied along with common salt, or with superphosphate of lime.

291. *What is sulphate of soda?*

Sulphate of soda is the substance commonly called Glauber salts, and consists of sulphuric acid (oil of vitriol) and soda. It sometimes produces good effects when applied as a top-dressing to grass land, to turnips, to beans, and to young potato plants.

40 ℔. of sulphuric acid, with 31 ℔. of soda, form 71 ℔. of dry sulphate of soda.

44¼ of dry sulphate of soda, and 55¾ of water, form 100 ℔. of *crystallised* sulphate of soda, or common Glauber salts. By drying in an oven, all the water is driven off from the crystallised salt, and the dry (or anhydrous) salt remains.

292. *What is sulphate of magnesia?*

Sulphate of magnesia, commonly known by the name of Epsom salts, is a bitter saline substance, consisting of sulphuric acid and magnesia.

100 parts of *dry* sulphate of magnesia consist of 34 of magnesia and 66 of sulphuric acid. The crystallised Epsom salts sold in the shops contain 51 per cent of water.

This salt has been recommended as a top-dressing for wheat and for the potato, and is employed in the manufacture of artificial manures.

A boy will soon learn, by the taste alone, to distinguish between common salt, nitrate of soda, sulphate of soda, and sulphate of magnesia. In regard to this mode of distinguishing them, questions at once instructive and amusing will suggest themselves to the teacher.

293. *What is sulphate of ammonia?*

Sulphate of ammonia is a white crystallised substance, consisting of sulphuric acid and ammonia. It is often applied profitably to young grain crops in spring.

100 lb. of sulphate of ammonia contain 23¼ lb. of ammonia, 53¼ lb. of acid, and 24 lb. of water.

To crops of grain which look yellow and sickly in spring, a top-dressing of this salt, or of nitrate of soda, has been found very profitable when applied at the rate of 1 cwt. or 1½ cwt. per acre. It is one of the most useful ingredients in soot (Q. 306.)

294. *How is common salt applied?*

Common salt may either be applied as a top-dressing, or it may be mixed with the farmyard or other manure, or with the water used in slaking quicklime.

100 lb. of common salt consist of 60 of chlorine, and 40 of a metal called *sodium*, which, with oxygen, forms soda. Its chemical name, therefore, is chlorine of sodium. It exists in, and is necessary to, all cultivated plants, especially to root crops, such as turnips and mangold-wurzel, to leaf crops, like cabbage, and to young shoots, like asparagus. When applied to grain crops, common salt almost always increases the weight per bushel of the grain when reaped. Mixed with quicklime, and put on the land, it gives strength to the straw.

295. *In what places is salt most likely to be beneficial?*

In places that are remote from the sea, or are sheltered by high hills from the winds that pass over the sea.

296. *Why is it likely to be less useful near the sea?*

Because the sea-winds bring with them a portion of the sea-spray, and sprinkle it over the soil at a distance of many miles from the sea-shore.

297. *What is gypsum?*

Gypsum is a white solid substance, composed of sulphuric acid and lime. It forms an excellent top-dressing, upon many soils, for red clover, and for the pea and bean crops; and is recommended for strewing upon fermenting dung-heaps, or on the moist floors of stables, for the purpose of fixing the ammonia produced during fermentation.

40 lb. of sulphuric acid, and 28½ lb. of lime, form 68½ lb. of *burned* gypsum, which contains no water.

40 lb. of acid, 28½ lb. of lime, and 18 lb. of water, form 86½ lb. of native or unburned gypsum. Native or unburned gypsum loses about 21 per cent of water when heated to dull redness, becoming burned gypsum.

The teacher may heat a little unburned gypsum on the end of a knife (fig. 2), or in a tube over the candle; and show, *first*, that it becomes opaque and milk-white; *second*, loses water, and becomes lighter; and *third*, that, after heating, it readily crumbles to a fine white powder.

This fine white powder is the plaster-of-Paris, or *stucco*, which is used for making casts, and for the cornices of rooms.

298. *What do you mean by fixing ammonia?*

Bringing it into a state in which it will escape less readily into the air.

The *carbonate* of ammonia of fermenting manures is by moist gypsum converted into sulphate of ammonia, which is less volatile, or more *fixed*, when exposed to the air.

299. *Under what circumstances ought these salt-like or saline substances to be applied?*

They ought to be applied in calm weather, in order that they may be equally spread; and soon after or before rain, that they may be dissolved in the soil.

300. *And at what season of the year?*

Generally in spring, when the young crops begin to shoot; and in the case of grass, soon after every cutting.

301. *Are mixtures of these substances sometimes more beneficial than any of them applied singly?*

Yes. A mixture of nitrate and sulphate of soda usually produces a much more beneficial effect upon potatoes than either of them alone. The same is often the case with a mixture of common salt and gypsum upon the bean crop, of common salt and nitrate of soda upon wheat, and with mixtures of this nitrate and the salts of ammonia upon every crop.

The teacher will find some useful particulars upon this point in the Author's *Elements of Agricultural Chemistry and Geology* (sixth English edition, p. 270,) which he may consult with advantage for the purpose of explaining the subject more fully to his pupils when he shall think it proper to do so.

302. *What is kelp?*

Kelp is the ash that is left when sea-weed is burned in large quantities.

303. *Can it be employed usefully as a manure?*

Yes. As a top-dressing to grass lands and to young corn.

For the turnip and potato crops, it may be tried on some soils with advantage, either alone, at the rate of 4 to 6 cwt. an acre, or with half the usual application of farmyard manure. Of course the kelp will not do so much good as the sea-weed from which it is prepared, because the useful organic matter of the sea-weed has been burned away; but it is more portable, and is capable of being applied where sea-weed itself cannot be, and is therefore deserving of a trial.

304. *Has kelp been much employed as a manure?*

Not hitherto; but there is reason to believe that, if fairly tried, it might be profitably employed to a large extent.

Charred sea-weed and fish-refuse mixed together would mutually improve and assist the use of each other.

305. *Are wood ashes (or the ashes of burned wood) a valuable manure?*

Yes. When applied to grass lands, wood-ashes destroy moss

and increase their luxuriance. Upon young corn and potatoes they produce a beneficial effect, and they are profitably mixed with bones, rape-dust, guano, and other manures which are employed for the turnip crop.

In Lower Canada, 40 bushels of wood-ashes, applied alone to some soils, give a crop of 200 to 250 bushels of potatoes.

306. *How is coal-soot used as a manure?*

It is applied as a top-dressing to grass land, as a manure for potatoes, and as an admixture with other manures.

Soot contains lime, gypsum, and sulphate of ammonia, the latter sometimes to the extent of one-eighth part of the whole weight of the soot. To the last of these substances its efficacy as a manure is very much owing.

307. *What visible effects do soot, the salts of ammonia, and the nitrates, produce upon the crops?*

They give them a rich and luxuriant green colour, and make them more juicy and succulent.

SECT. XVII.—OF LIMESTONE, AND OF THE BURNING AND USE OF LIME.

308. *What does limestone consist of?*

Limestone consists of lime (*quick*-lime) in combination with carbonic acid.

28 ℔. of lime, and 22 ℔. of carbonic acid, make 50 ℔. of pure limestone. The teacher may here revert to the properties of carbonic acid and lime, and examine his pupils upon what they had previously learned as to these substances.

309. *What name is given to limestone by chemists?*

It is called by chemists *carbonate of lime.*

310. *Are there many varieties of limestone?*

Yes. Some soft, such as chalk; some hard, such as our common limestones; some of a yellow colour, like many of the magnesian limestones, which contain magnesia; some pure white, like statuary marble; some black, like the Derbyshire black marble; and so on.

Here it would be advantageous if the teacher could exhibit some of the above or of other varieties of limestone.

311. *What is marl?*

Marl is the same thing as limestone—namely, carbonate of lime; only it is often met with in a soft state, or in that of a fine powder: and often, also, mixed with sand and clay.

Marls contain variable proportions of lime. In some there is less than 20, in others 80 or 90 per cent of carbonate of lime.

312. *Do limestones and marls contain any other compound of lime that is favorable to vegetation?*

They contain usually a minute quantity of phosphate of lime.

In limestones, the phosphate occasionally amounts to 1½ per cent, and in some few marls, to 2, 3, or 4 per cent. Such quantities of phosphate of lime sensibly increase the value of the lime or marl, for agricultural purposes. Beds of marl are sometimes found in the green-sand formation, which contain from 6 to 14 per cent, or even more, of phosphate of lime. (Q. 285, note.)

313. *What is shell-sand?*

Shell-sand, or broken sea-shells, is also nearly the same thing as common limestone.

314. *Can these marls and shell-sands be applied with advantage to the land?*

Yes. As a top-dressing to grass lands, and especially to sour, coarse, and mossy grass. They may also be ploughed or harrowed into arable land, and may be applied with great advantage, and in large quantity to, peaty soils.

315. *Can they not be used also in making composts?*

Yes. When mixed with earth and vegetable matter, such as peat or sea-weed; or with animal matter, such as dead animals, fish, fish-refuse, whale-blubber, &c., and even with farmyard dung.

316. *How would you ascertain the presence of lime in a soil, or in a substance supposed to be a marl?*

By putting a little of it into a glass, and pouring upon it either vinegar or weak spirit of salt (muriatic acid.) If any bubbling up (effervescence) appeared, I should say that lime was present.

317. *To what would this bubbling up be owing?*

It would be owing to the escape of carbonic acid gas from the carbonate of lime which the soil or marl contained.

The teacher may perform this experiment by pouring weak acid upon marl or powdered chalk in a wine-glass, and showing the bubbling up. He may further convince his pupils that the gas given off is really carbonic acid, by introducing a lighted taper into the glass, and so on. (See Q. 43.)

318. *What takes place when limestone (carbonate of lime) is burned in the kiln?*

The carbonic acid is driven off from the limestone by the heat, and the lime alone remains.

The teacher may here pour diluted muriatic acid upon a few bits of limestone in a beer-glass, and show that carbonic acid is given off by, and therefore *is contained in the limestone.* He may then pour the same acid upon a piece of well-burned lime, and show that no gas is given off, and therefore that *no carbonic acid is contained in the quicklime.* It *has been* driven off by the heat, as the answer says.

The habits of observation, as well as the reasoning powers of boys, cannot fail to be strengthened by such experimental demonstrations as these.

319. *What is the lime called in this state?*

It is called burned lime, quicklime, caustic lime, hot lime, lime-shells, &c.

The teacher may show the caustic or alkaline property of quicklime, by putting a little of it into a solution of vegetable-blue colour (litmus or

red cabbage,) which has previously been reddened by a few drops of acid, when, like ammonia, it will restore the blue colour. The taste is also decidedly alkaline.

320. *What weight of quicklime or lime-shells is obtained from a ton of limestone?*

A ton of pure limestone yields about 11½ cwt. of quicklime.

321. *What takes place when water is poured upon quicklime*

The quicklime drinks in the water, becomes very hot, swells up, and gradually falls to powder.

Fig. 25.

The teacher may exhibit this effect of water upon lime by pouring water upon it, as in fig. 25, and may satisfy his pupils that the heat produced is great, by showing that it will sometimes set fire to gunpowder placed upon a dry portion of the lime, or will heat a cold baked pie when put in the middle of it. He may also explain to them that it is the heat thus given off which occasionally sets fire to the sods with which heaps of lime-shells are sometimes covered up in the fields.

It requires a piece of very good and well-burned lime to fire gunpowder in this way; but the experiment will be more sure to succeed if sulphuric acid, diluted with one or two waters, be used instead of pure water. The mass will become so hot as readily to kindle gunpowder. In this case, however, it will be *gypsum* (sulphate of lime,) and not merely *slaked lime*, that will be produced.

322. *What is this pouring of water upon lime, so as to make it fall, usually called?*

It is usually called slaking the lime, and the lime is called slaked or slacked lime.

323. *Does the quicklime increase in weight when slaked?*

Yes; one ton of *pure* quicklime become 26½ cwt. of slaked lime.

This may be shown by weighing a piece of lime, slaking it, and then weighing it again after it has fallen to a fine powder. If the lime be impure, the increase of weight will generally not be so great as it ought to be if pure.

324. *Does quicklime fall to powder of itself, when left exposed to the air?*

Yes; it absorbs water from the air, and gradually falls to powder.

325. *Does quicklime drink in (absorb) anything else from the air?*

Yes; it gradually drinks in carbonic acid from the air, and returns at length to the state of carbonate.

The teacher may here satisfy his pupils that lime does thus absorb carbonic acid from the air, by pouring a little lime-water into a wide-mouthed glass or into a saucer, and showing them that an insoluble film of

white *carbonate of lime* gradually forms on its surface, where it is in contact with the air. This experiment may be exhibited for the purpose of showing two things—*first*, that carbonic acid exists in the air (Q. 44); and *second*, that quicklime absorbs it, and forms this film.

326. *When it has thus returned to the state of carbonate, is it better for the land than before it was burned?*

Yes; it is in the state of a far finer powder than could be got by any other means, and can thus be more thoroughly mixed with the soil.

327. *What is it usually called when it has thus returned to the state of carbonate?*

It is usually called mild lime, to distinguish it from the quick or caustic lime.

328. *Does quicklime act in a different way upon the land from mild lime?*

It acts very much in the same way, but more quickly.

329. *How do they both act?*

They act principally in four ways—*first*, by supplying the lime which all plants require as part of their food; *second*, by combining with acids in the soil, so as to remove the sourness of the land; *third*, by gradually disposing the vegetable matter of the soil to change into soluble food for plants; and, *fourth*, by acting upon the mineral matter of the soil so as to fit it for entering into the roots of growing plants.

The teacher may mix a little slaked lime with vinegar, or with weak muriatic or sulphuric acid, and show that it very soon takes away the sourness of the liquid. In the soil it acts in a similar way.

330. *Would you prefer a pure lime to one containing a considerable per centage of magnesia or earthy matter?*

I would prefer a pure lime for laying upon the land.

Magnesia, in a limestone, is easily detected by dissolving the limestone in vinegar or muriatic acid, and adding lime-water to the clear solution. If the lime-water make it milky, it contains magnesia. It ought to be remembered, however, that unless the soil naturally contain a considerable per centage of magnesia, the presence of a small proportion of magnesia in the lime applied to it (2 or 3 per cent) will make it more valuable to the land, because, as we have seen, magnesia is one of those substances of which grain especially exhausts the soil. (Q. 181.)

331. *Would you bury lime deep, or would you keep it near the surface?*

I would always keep it near the surface, as it has a natural tendency to sink.

332. *To what land would you apply quicklime rather than mild lime?*

I would apply quicklime to peaty soils, to heavy clay-soils, to arable lands which are very sour, and to such as contain a great deal of vegetable matter.

333. *In what state is slaked lime said to produce the most lasting effect on hill pasture?*

It is said to produce a more lasting effect, when applied after it has become wet by exposure to the air and rain, than when put on in a dry and newly-slaked state.

In Dumfriesshire, in Scotland, the lime is said to be *dabby* or *dracket* when in this state of wetness.

334. *Will the same quantity of lime produce as great an effect upon wet as upon dry or drained land?*

No; the same quantity will produce a greater effect upon drained or naturally dry land than upon wet land.

335. *What quantity of quicklime is usually added to arable land in this country?*

It is usually added at the rate of eight or ten bushels a-year to each acre.

336. *Is it added every year?*

No; it is added every *rotation*, or every second rotation, or sometimes only once in the nineteen years.

The teacher may here explain the meaning of the new word *rotation*, and may illustrate it by reference to the course of cropping in his own or in the neighbouring states; and if he make himself master of the theory of rotations, especially of the necessity and reasons for a change of crops on all soils (see the Author's *Lectures on Agricultural Chemistry and Geology*), he may, in conversation, give his pupils most profitable notions upon this subject, which they will seldom forget in after-life.

337. *Would you rather apply the lime in large doses at long intervals, or in small doses at shorter intervals?*

If I applied a large dose of lime at the beginning of my occupation of a farm, I would apply smaller doses at the end of each *rotation*, or at the end of every second rotation, to keep up the quantity of lime in the land.

338. *Why does lime require to be repeated?*

Chiefly for three reasons—*first*, because the crops eat up every year and carry off a portion of the lime; *second*, because a portion of it sinks into the subsoil; and, *thirdly*, because the rains are always washing a portion of it out of the land.

For more on the important subject of lime, the Author's work *on the Use of Lime in Agriculture* may be consulted with advantage.

SECT. XVIII.—OF THE PROPORTIONS OF STARCH, GLUTEN, AND FAT CONTAINED IN THE CROPS WHICH THE FARMER USUALLY REAPS.

339. *Of what nutritive substances do the different kinds of cultivated grain and roots chiefly consist?*

They consist chiefly of three substances—starch, gluten, and oil or fat.

340. *What proportion of each of these usually exists in wheat, barley, or rye?*

100 lb. of rye, barley, or wheaten flour contain about 55 lb. of starch, 10 lb. of gluten, and 2 or 3 lb. of oil.

Rye is the principal food of the Northern nations of Europe south of Lapland, as far as the Rhine. Barley is remarkable among grains for ripening as far north as north-western Lapland, and occasionally in Iceland, and as far south as the high grounds beneath the equator.

341. *In what proportions do they exist in unshelled oats?*

100 lb. of good oats contain about 40 lb. of starch, 10 lb. of gluten, and 4 lb. of oil.

Oats are the national food of Scotland, which produces better samples of this grain than any other country. Eaten as the *sole* food, oatmeal is heating to the skin, and in some constitutions produces boils.

342. *In what proportions do they exist in Indian corn?*

100 lb. of Indian corn contain about 60 lb. of starch, 10 lb. of gluten, and 5 lb. of fat.

The proportions of starch and fat or oil differ much in different varieties of Indian corn. The Tuscarora corn, for example, contains much starch, and the pop-corn much oil—sometimes as much as 10 per cent.

Maize or Indian corn is the only bread-corn of tropical America, and is a principal food in the United States of North America. In 1850, the crop of maize in that Republic was estimated at 66 millions of quarters.

Fig 26.

Doora or Indian Millet.

343. *In what proportions do they exist in rice?*

100 lb. of clean rice contain about 75 lb. of starch, 7 lb. of gluten, and ½ lb. of fat.

Rice is the principal food of the East Indian and some other Eastern nations—with curry it is the staff of life in India. The finest samples come from South Carolina. It is remarkable as the kind of food by which a larger proportion of the human race is supported than by any other. It is less laxative than the other cereal grains. When substituted for potatoes in our workhouses it has sometimes induced scurvy.

344. *Is buckwheat a nutritive grain?*

It is more nutritive than rice, and nearly equal to wheat.

Buckwheat is cultivated in almost every country in the temperate regions, but it does not form the principal food in any.—(Consult JOHNSTON'S *School Physical Atlas*, Plate 15.)

345. *What is dhurra or doora?* (Fig. 26.)

Doora is a variety of millet. It is a small, round, white grain, very prolific, and as nutritious as wheat.

This grain is the staff of life over nearly all Northern Africa, and is much used in India and

the East. Occasional cargoes are brought to this country, but it is still little known or used among us.

346. *What proportions of these ingredients exist in beans or pease?*

100 lb. of beans or pease contain about 45 lb. of starch, 24 lb. of gluten, and 2 lb. of fat.

Beans and other pulse are chiefly remarkable for the proportion of gluten they contain, and for their constipating quality.

347. *In what proportions do they exist in hay?*

100 lb. of clover, or of rich English hay, contain 40 lb. of starch, 8 lb. of gluten, and 4 lb. of fat.

348. *Which kind of straw is the most nutritious?*

In our climate pea or bean straw, then oat straw, then barley and wheat straws.

Oat straw is sometimes more nutritious than good hay, but the time of cutting, the climate, the season, and the soil, all affect the feeding qualities of straw.

349. *What do potatoes, turnips, and other roots chiefly consist of?*

Their principal constituent is water.

350. *How much water is contained in* 100 *lb. of potatoes?*

100 lb. of potatoes contain about 75 lb. of water, and nearly 25 lb. of nutritive matter. (See Q. 20, note.)

351. *How much water is contained in* 100 *lb. of turnips, carrots, mangold wurzel?*

100 lb. of turnips contain about 88 lb. of water, and of carrots or mangold-wurzel about 85 lb.

The quantity of water in these roots is often greater than this, and consequently the proportion of dry nutritive matter less.

352. *What quantities of starch and gluten do potatoes contain?*

100 lb. of potatoes contain from 15 to 20 lb. of starch, and about 2 lb. of gluten.

The potato is remarkable for being grown over a greater range of latitude and altitude than any other cultivated plant. Its culture extends from the southern extremity of Africa to Lapland, Iceland, and Labrador, and from the sea level to a height of 13,000 feet on the Andes, and 4800 on the Alps. It is the national food of Ireland, which produces this root in great abundance and of excellent quality. In 1854 nearly a million of acres of potatoes were grown in Ireland. The dry nutritive matter of the potato is remarkable for being nearly identical in composition with that of rice. (Q. 343.)

353. *Are these proportions of starch, gluten, and oil or fat, always the same in the same grain or root?*

No; some varieties of wheat contain more gluten than others, some varieties of oats more oil than others, and some varieties of potatoes and Indian corn more starch than others.

Even the same variety, however, differs with the circumstances in which it is grown. The time of cutting also affects the composition of grain—the most profitable time for cutting wheat, in our climate, being two weeks, and for oats one week, before full or dead ripeness.

354. *What kinds of grain contain the largest proportions of fat and gluten?*

Oats, Indian corn, and the oily; seeds, contain most fat; beans and peas most gluten and least oil and oily seeds most gluten and oil together. (See note to Q. 359.)

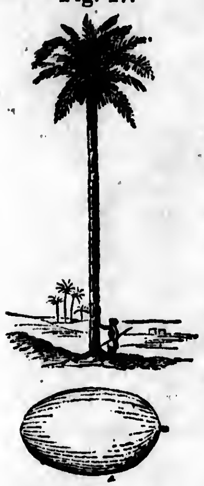
The teacher may here explain that oily seeds are such as yield oil by expression—linseed, rape-seed, poppy-seed, hemp-seed, &c.—may describe how the oil is expressed, what use is made of it, what of the refuse or cake left behind, and so on. (Q. 221.)

355. *What kind of green crops contains the largest proportion of gluten?*

The dry substance of the cabbage contains more gluten than any other crop we grow.

Thus, dried wheat contains 12, dried beans 28, dried potatoes 8, dried turnips 14, and dried cabbage 30 to 35 lb. of gluten in the 100.

Fig. 27.



The Date-tree.

Scale, 1 inch to 40 feet.
Fruit, 1 inch to 4 inches.

356. *Have the soil and climate any influence upon the proportions of these ingredients in different crops.*

Yes; the wheat of warm climates is said to contain more gluten, the potatoes and barley grown upon light or well-drained land more starch; and other crops are probably affected in a similar way.

Unripe potatoes also contain less starch than ripe ones.

357. *Is any nourishment contained in fruits?*

Yes. Dried figs, as they come to this country, are about as nutritious as the same weight of wheaten bread. Dried dates are considerably less so, though they are the bread of the desert. Raw apples are about equal to raw potatoes.

Wheaten bread contains about 45 per cent of water, dried figs 20 per cent.

The *date* is an important part of the general food in the desert regions of Northern Africa. Wherever a spring of water appears, the date tree (fig. 27) accompanies it. Among the oases of Fezzan, nineteen-twentieths of the population live upon it for nine months in the year! It is rich in sugar, but somewhat poor in gluten. This defect is generally made up by an allowance of camels' milk, or an occasional kid, or a handful of lentils.

Apples are much used in some parts of the United States for feeding milk-cows and pigs, and are reckoned about equal to their own weight of potatoes.

358. *When grain or potatoes are burned, do they leave any inorganic matter or ash?*

Yes; they all leave a small quantity of ash when burned.

359. *Of what does this ash consist?*

It consists of the phosphates of potash, soda, lime, and magnesia, of common salt, and other saline substances.

The teacher may here explain more fully the composition of this ash, by referring to the table under Q. 181, which exhibits the composition of the ash of different kinds of grain, and by explaining that the ash of grain crops, of root-crops, and of fruits, contains a certain quantity of all the substances there mentioned; but that the combinations of phosporic acid with potash, soda, magnesia, and lime, are its *most important* ingredients. The following table exhibits a summary of what is contained in the present section. It may be advantageously printed in calico, and suspended on the walls of the school-room, along with other tables given in the preceding part of the Catechism:—

	Water	Husk and fibre.	Starch and sugar.	Gluten	Fat.	Ash.
Wheat	15	15	55	10	3	2
Barley	15	15	55	10	2	3
Oats	16	20	40	10	4	4
Rye	12	15	55	10	3	2
Rice	12	3	75	7	3/4	1
Indian corn	14	6	65	10	5	2
Buckwheat	?	?	?	10	?	2
Beans	14	10	45	24	2	3
Potatoes	75	3	16	2	1/6	1
Dried potatoe	—	11	76	8	1	4
Turnip	88	—	8	1½	1/8	3/8
Dried turnip	—	—	77	14	3	6
Carrot	85	—	10	1½ to 2	?	?
Cabbage	90	—	4	3 to 3½	2/3	3/4
Dried cabbage	—	?	40	30 to 35	4	10
Linseed, rape, and poppy cakes	12	?	—	35	12	7
Dried figs	21	—	73	6	—	—
Dried dates	23	—	63	8	—	2

The turnip, carrot, and cabbage do not in reality contain starch, but they contain the proportions here indicated of other substances which serve the same purpose as starch in the feeding of animals. (See Q. 3'3, note).

SECT. XIX.—USES OF THE STARCH OF OUR CROPS IN THE FEEDING OF ANIMALS.

360. *What natural purposes are vegetables intended to serve?*

They are chiefly intended for the food of animals.

361. *What substances must an animal derive from its food that it may be maintained in a healthy state?*

It must obtain starch, gluten, oil or fat, and saline or inorganic matter.

362. *Do you recollect what starch consists of?*

Starch consists of carbon and water. (Q. 78.)

363. *For what purpose does an animal require starch in its food?*

It requires starch to supply the carbon which it throws off from its lungs during respiration.

The teacher may here explain that gum and sugar, which also consist of carbon and water only (Q. 78), serve the same purposes when eaten as the

starch of our food does; and that what is here said, for simplicity, of starch only, is true also of the sugar and gum contained in the vegetable substances we eat, as well as of the peculiar substance (*pectose or pectic acid*) contained in the turnip, carrot, and mangold-wurzel.

364. *Do you recollect how much carbon a man throws off from his lungs in a day?*

Yes. He throws off from 6 to 8 ounces in a day. (Q. 259.)

365. *What quantity of starch must he eat, in order to supply this quantity of carbon to be given off from his lungs in a day?*

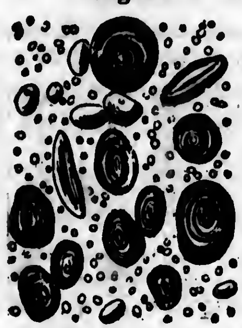
He will require to eat nearly a pound of potato starch in a day.

10 ounces of starch contain about 4½ ounces of carbon. (Q. 78.)

Fig 28.

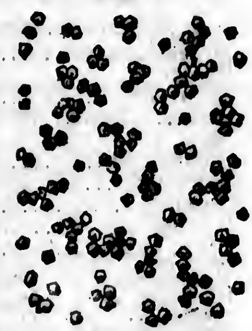
Potato starch.

Fig. 29.



Wheat starch.

Fig. 30.



Rice starch.

The little grains of starch, when magnified 62,500 times, are seen to be singularly formed, and of different shapes and sizes—as represented in figs. 28–30. Those of rice are particularly small and angular. Whether these differences in any way affect the value of different kinds of starch for food is not known.

366. *In what form is the carbon given off from the lungs of animals?*

It is given off in the form of carbonic acid gas.

This may be here shown again, by breathing through lime water, as described in the note to Q. 88.

367. *For what purpose does the animal undo what the plant has done, by re-converting the carbon of the starch into carbonic acid.* (Q. 80.)

The purpose is to keep the animal warm.

If starch be burned in the air, it will, like wood, give out much heat, and be converted into carbonic acid and water. In the animal body it is converted into carbonic acid and water, and, in the act of being so converted, is believed to give off heat slowly in the body, as it does when it is burned in the air, and thus to keep up the natural warmth.

368. *What becomes of the carbonic acid gas thus given off?*

It is diffused through the air, and is afterwards absorbed again by plants, in order that new quantities of starch may be produced from it.

The teacher may here appropriately draw the especial attention of his pupils to the beautiful cycle of natural operations above described. Even children may be made to see the beauty and bounty of the process by

which the same carbon is again and again transformed by the plant into starch, and by the animal into carbonic acid, as well as the purpose for which these changes are made to take place—namely, *to keep up the warmth of the animal body.*

SECT. XX.—USES OF THE GLUTEN, FAT, AND MINERAL MATTER OF PLANTS IN THE FEEDING OF ANIMALS.

369. *What purpose is served by the gluten of vegetables in the feeding of animals?*

It builds up the muscles or lean part of the body.

370. *But for what purpose does an animal require gluten in its food after it is full grown?*

A full-grown animal requires gluten for the purpose of repairing the daily waste of the muscles of its body.

371. *Are the muscles of an animal really subject to waste?*

Yes. Nearly all the parts of the body suffer a certain waste every day.

It is believed that all the parts of the body of a well-fed man are removed or renewed once in the course of every thirty or forty days. Yet this is done so imperceptibly that the old scars on the body remain! The more exercise a man takes, the more bodily labour he performs, or *the more he thinks*, the faster is his body wasted, and, if he has food enough, renewed. When no food is taken, the body loses in summer one-fourteenth, in winter one-twelfth, of its weight in twenty-four hours!

372. *What becomes of the part that thus wastes away?*

It is carried through the body, and forms part of the dung and urine of the animal.

373. *How can the gluten of plants repair the waste of the muscles or lean part of the animal?*

Because the gluten of plants is almost exactly the same thing as the muscular part of animals.

374. *Will those kinds of food which contain most gluten be most fitted, therefore, to build up and increase the muscles or the muscular strength?*

Yes; such as beans, peas, linseed-cake and cabbage.

A working horse, for example, will lose strength if fed upon potatoes only, but with an addition of beans, it will work well.

375. *Why does the animal require oil or fat in its food?*

To supply the natural waste of fatty matter which takes place.

376. *Does it serve any other purpose?*

Yes. When more is given than is necessary to supply the waste, it *may* make the animal fat.

377. *Is food that contains much oil, then, the best for fattening?*

Yes. Of two samples of food, that which contains the most oil will *generally* fatten most quickly.

378. *Is this the reason why linseed and oil cakes, and, in a less degree, Indian corn, are so good for fattening stock?*

Yes; it is one reason. (Q. 359, note.)

About 80,000 tons of linseed cake are imported annually into Great Britain, as food for cattle, at a cost of nearly £70,000. In the county of Rutland, it has been found profitable to mix linseed oil with the other food given to cattle.

Poppy-cake is by some supposed to be dangerous as a food for cattle; but this is not the case. Poppy-seed puddings are a constant favourite Christmas dish in Hungary.

Rape-cake, from its hot taste, is not relished by cattle; but they eat it readily when mixed with a little molasses, or boiled with half its weight of bean-meal, and mixed with cut straw. Sheep eat it freely while they are fed upon cabbage, or abundantly supplied with water.

379. *What purpose is the inorganic or mineral matter of plants intended to serve in the feeding of animals?*

It is intended to supply mineral matter to the different parts of the body, as the soil supplies them to the plant.

380. *Are these mineral substances necessary to the animal at all stages of its growth?*

Yes. A certain daily portion is always necessary to supply the daily waste of the mineral matter of the bones, of the salts in the blood and in the muscles, &c.

381. *What kind of mineral matter does the animal principally require, to build up and repair the waste of its bones?*

Phosphate of lime is the kind of mineral matter which is principally required by the bones. (Q. 233.)

The body of a full-grown man contains from 9 to 12 ℔. of dry bone, which yields, when burned, from 6 to 8 ℔. of bone earth. Common salt is the principal mineral matter in the *blood*, and phosphate of potash in the *flesh*.

382. *Do not the gluten, fat, and saline matter serve a double purpose when the animal is growing?*

Yes. When the animal is growing, they not only supply the daily waste, but are daily adding to the weight of the animal's body.

383. *Will a growing animal, on this account, require a larger supply of these kinds of food?*

Yes. A growing animal of the same weight will require more of these kinds of food than an animal which is already full-grown.

To *sustain* an animal, if not hard worked, requires about one-sixtieth part of its weight of good hay; to increase or fatten it, or enable it to give milk, about a *thirtieth* part, or twice as much.

384. *Suppose an equal quantity of the same kind of food given to a growing and a full-grown animal, which of them will give the richer dung?*

* The full-grown animal will give the richer dung.

385. *Why so?*

Because the growing animal extracts and retains more of the substance of the food.

386. *Why does it do this?*

Because it has both to supply the natural waste of its own body and to add to its size, while the full-grown animal has only to supply the daily waste.

387. *Why is the dung of fattening stock richer than that of growing stock, or of cows in milk?*

Because fattening stock extract and retain chiefly the oil and starch of their food, and reject more of the remainder than other stock do.

Yet much of the enriching gluten of the food is always found in the dung. When sheep consume about 1 lb. of rape a-day, and cattle in proportion, 5-6ths of the nitrogen or gluten of the food in the case of the sheep, and 7-8ths in that of the cow, is found in the dung.—WOLFF.

388. *How would you convert a ton of oats, Indian corn, turnips, or hay, into the largest quantity of beef or mutton?*

I would keep my cattle or sheep in a warm or sheltered place, where they might have wholesome air, and but little light; and I would disturb them as little as possible.

389. *If you wanted merely to fatten a full-grown beast, what would you do?*

I would keep it warm, disturb it little, and give it fat or oily food—oil-cake, oats, Indian-corn, boiled linseed jelly, &c.—with a good supply of turnips.

The degree of warmth and confinement under which animals will thrive depends much upon the breed. The hardy and wild *West Highlander* may pine away in the warm and confined sheds in which the *Teeswater* ox thrives best; and the *black-faced* sheep may lose flesh and become unhealthy where the delicate *Leicester* thrives and fattens.

390. *If you wished only to convert a large quantity of hay, straw, or turnips into manure, what would you do?*

I would put my stock in a cool and less sheltered place, and I would make them take a good deal of exercise.

391. *As a general rule, in fattening off milk-cows or pigs, would you give the food sweet or sour?*

To pigs I would give it slightly sour; to fattening cows and bullocks I would give it fresh and sweet.

In some of the great London dairies, the brewers' grains are trodden while hot into deep pits lined with brick, and covered over with a layer of earth, so as to exclude the air. Treated in this way, they are said to become sweeter and more nutritive by keeping, and are considered none the worse for being several years old.

392. *Why would you give it sour to pigs?*

Because it has been found by experience that more pork is obtained from green vegetables, or from bean-meal, boiled potatoes, &c., when mixed with water and left to sour, than when given fresh and sweet.

It is curious that all tribes of men which live chiefly upon milk prefer to drink it sour.

393. *Is there any profit in crushing, cooking, or mixing food?*

Yes. When crushed or cooked, the food is more completely digested, and goes farther. Upon mixed food, the animal can be fed to a greater weight.

The Shakers of Lebanon in the United States give as the result of their experience in feeding 1⅛ million pounds of pork with Indian corn—that
3 of ground are equal to 4 of unground Indian corn.
3 of cooked " " to 4 of raw Indian corn-meal.

394. *Why is hard or dry food generally given in feeding off animals for the butcher, especially when they are to be salted?*

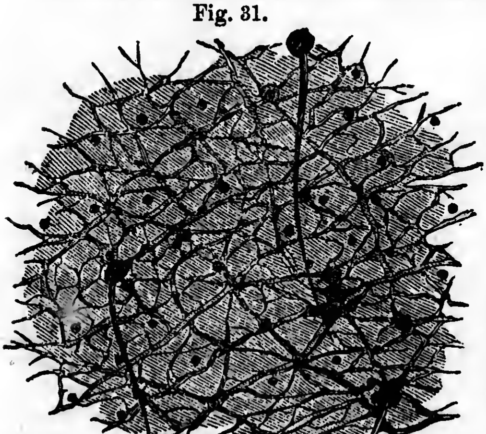
Because then the fat is harder, the meat takes in the salt and keeps better, and it shrinks less both in salting and in cooking.

395. *Is there anything else you would do to make your stock-feeding more profitable?*

Yes. I would keep my cow-houses well ventilated, but warm, and my sheep and pigs clean; I would curry my cattle occasionally, and I would feed them at regular intervals, and at least three times a-day.

The importance of currying and keeping the skin clean may be inferred from the fact, that the skin of a man contains seven millions of pores, which are the mouths of the little tubes by which the perspiration escapes. They are distributed as shown in the annexed wood-cut (fig. 31.) Neither man nor animal can long be in good health if, by allowing dirt to collect on the skin, these pores be closed.

Fig. 31.



Surface of the Cuticle greatly magnified, showing the pores and hairs.

396. *What are the sources of profit in keeping good breeds of stock and in feeding them well?*

The sources of profit are these: *First*, Good stock come to earlier maturity, and give more beef, mutton, or pork from the same weight of food, of a better quality, and in a shorter time. *Second*, When well fed they make a larger quantity of rich manure, which enables the farmer, from the same extent of land, to raise larger crops than before.

All these facts regarding the use and effect of different kinds of food in the fattening of stock, are subject to many modifications in actual practice. The *breed* of the animal, its individual *constitution and temper*, and the *circumstances* in which it is kept, all influence the result of the feed-

ing. The *proportions* in which different varieties of food are mixed, and the *period* of the fattening at which a given weight of any food is consumed, also affect the increase of the animal's weight. Both in sheep and pigs, less is laid on, from the same weight of food, the fatter the animal becomes. Such things as these the teacher may advert to, by way of explaining how it so often happens that the same kind and quantity of food produces upon different animals results so unlike.

SECT. XXI.—OF MILK AND DAIRY PRODUCE, AND THE FEEDING OF MILCH COWS.

397. *What does milk consist of?*

Milk consists of water, curd, butter or fat, and a peculiar kind of sugar called milk-sugar.

A hundred ℔. (or 10 gallons) of cows' milk contain about 4½ ℔. of pure curd, 3 of fat or butter, and 4½ of milk-sugar—nearly all the rest is water. When new milk is set aside, the fat rises in the form of cream, and can be skimmed off; a little vinegar or rennet separates the curd, and the sugar is obtained by evaporating the whey. This sugar has the same composition as cane-sugar, but is harder and not so sweet. (See Q. 78, note.)

398. *What does common butter consist of?*

It consists of fat, water, and a very little curd.

A hundred ℔. of fresh butter contain 10 or 12 ℔. of water, and about 1 of curd. The rest is fat.

399. *What does cheese consist of?*

Cheese consists of pure curd, butter or fat, and water.

A hundred ℔. of cheese contain from 30 to 45 ℔. of water. Skim-milk cheese contains from 6 to 10 ℔. of butter in the hundred; full-milk cheese from 20 to 30 ℔. of butter, and about as much pure curd, in the hundred. About ninety thousand tons of cheese are made yearly in England, eight thousand in Scotland, and four thousand in Ireland.

400. *Are the quantity and quality of the milk affected by the kind of food given to the cow?*

Yes; both are affected by the way in which the cow is fed.

401. *If you wished to make a cow give you the largest possible quantity of milk, how would you feed her?*

I would give her rich juicy grass or clover, turnips with their tops, green rye, brewers' grains, warm mashes, or other food containing much water, and I would supply her with whey or water to drink when she would take it.

It is said that if a cow be liberally supplied with whey, a very copious yield of milk is obtained. Sour drinks are also very grateful to milch cows.

402. *But to obtain milk of the best possible quality, would you do so?*

No. I would then give her drier food—such as oats, beans, bran, oil-cake, and clover hay, along with her turnips or boiled food.

403. *If you wanted milk particularly rich in butter, what would you give?*

I would give her the same kind of food as I would to a fattening animal—oil-cake, oats, barley, Indian-corn meal, and some turnips.

One lb. of oil-cake causes a cow to yield 1 lb. more milk, and makes all the rest richer. Two lb. a-day may be given if the milk is to be sold or used as milk. If butter is to be made, 1 lb. is enough, as more gives the butter a taste.

404. *But if you were going to make cheese of your milk, would you give the same kind of food?*

I would then prefer beans, pease, vetches, and clover, or clover hay, with oil-cake—all of which make the milk richer in curd.

405. *Why do they make it richer in curd?*

Because they contain a very large proportion of gluten, which has nearly the same composition and properties as the curd of milk.

The feeding with whey thickened with meal or grains is said, in the State of New York, to have increased the yearly produce of cheese from a single cow by upwards of a hundred lb. If so, it must be more profitable to use whey in this way than to give it to pigs.

406. *Does milk contain all the elements of a nutritious food?*

Yes. The butter of milk supplies fat to the body, the curd supports the muscles, and the milk-sugar supplies the carbon for respiration. Further, the ash or mineral of the milk supplies phosphates for the bones and flesh, and salts for the blood.

The teacher may here examine his pupils as to the proportion of phosphates, &c. in milk (Q. 237, note,) and may illustrate the striking analogy in composition which exists between this *animal* food, prepared by the *mother* for her young, and the *vegetable* food produced by the *soil* for the general sustenance of man, and of all other animals. How truly the earth is our mother!

When examining them on these latter parts of the subject, the teacher may draw the attention of his pupils also to the beautiful chemical connection which exists between the vegetable and animal kingdoms, and especially to the marked adaptation of the *living vegetable to the wants of the living animal*, which is exhibited in the fact, that the animal finds, ready formed in the ripened plant, as the young animal does in the mother's milk, all the most important substances of which its own body is composed. The gluten of the food it eats is nearly identical with the fibre of its muscles; the oil is similar in character to the fat of its body; the bone-earth, and other salts of the plant, supply mineral materials for its bones, blood, and flesh; while the starch and sugar afford the carbon which is required for the purposes of respiration, and for keeping the body warm. Finally, he may also point out that, when the vegetable food has discharged its office in the animal body, it returns to the earth in the form of dung, only to enter into the roots of new plants, and thus to produce new supplies of sustenance for other generations of animals. The entire economy of vegetable and animal life, and all the changes experienced by dead matter, are parts of one system—express, as it were, but one idea—the offspring of ONE MIND.

By a little reflection on the various subjects treated of, he may thus engraft a course of instruction in Natural Theology upon the purely practical principles of this little book; and may thus make it instrumental, not only in the intellectual, but also in what is much more important—the *moral* training of his pupils.

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